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M. O. P. IYENGAR

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A NOTE ON THE ORIGIN AND NATURE OF THE STARCH SHEATH IN *HERACLEUM* STEM

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Received for publication on August 15, 1945

INTRODUCTION

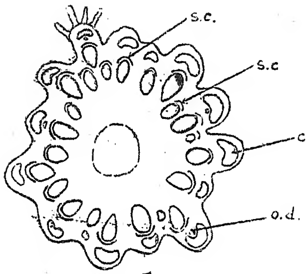
THE innermost layer of cortical cells, which is normally derived from the periblem and which encloses the plerome in the form of a sheath, has been described by Sachs[18] as the *plerome sheath*. Strasburger (1930) has named this layer *phlœoterma*. The plerome sheath differentiates in two principal forms, *viz.*, (1) as the *endodermis* with the characteristic structure of its walls, and (2) the *starch sheath*. Schoute (1902), however, uses all the three terms, *viz.*, *endodermis*, *stärkescheide* (starch sheath) and *schutzscheide* (protective sheath) in the description of the stems of angiosperms in his treatise on the Stelar Theory.

The starch sheath, as defined by de Bary (1884), comprises a single layer of cells, which agrees with endodermis only in the close lateral connection of its elements, but differs from the latter in the absence of Casparian strips and other wall characteristics. The cells of the starch sheath, when the latter is well defined, differ from the neighbouring cells by permanently containing small but movable starch grains in abundance (p. 414). In many cases, however, de Bary points out, the two forms are mutually replaceable even in the same region of allied plants. Thus the plerome sheath is found as a starch sheath in the hypocotyledonary stem of *Helianthus annuus*, but as endodermis in the same region of *Tagetes patula* (p. 415).

Endodermis is a conspicuous and constant feature in the roots of all vascular plants with the exception of the Lycopodiaceæ[12]; it is present in the stems of pteridophytes, in the leaves of gymnosperms, in the rhizome of land plants and in the stems of water plants[24]; but it is mostly absent in the stems of gymnosperms, in the aerial stems of angiospermous land plants and their leaves. Starch sheath, on the other hand, is found in the stems of most dicotyledons; but in stems

with abundant starch reserve in cortical cells the starch sheath as a layer is less conspicuous. Schoute (1902) observes that starch grains may be present in all the cells of the cortex, or in the innermost two or three layers, or only in the innermost layer of cells abutting on the stelar region. It is only in the last case that one should call the layer a starch sheath.

In most adult stems where starch sheath is developed, the layer appears in transverse section as a complete ring, *e.g.*, *Ricinus*, *Helianthus*, *Tagetes*, etc., but in some cases, such as *Brassica oleracea*, it is incomplete and is found only opposite the leaf-trace bundles ; and in *Aliangene alpina*, only opposite to the medullary rays of the central cylinder (de Bary, 1884, pp. 414–416).



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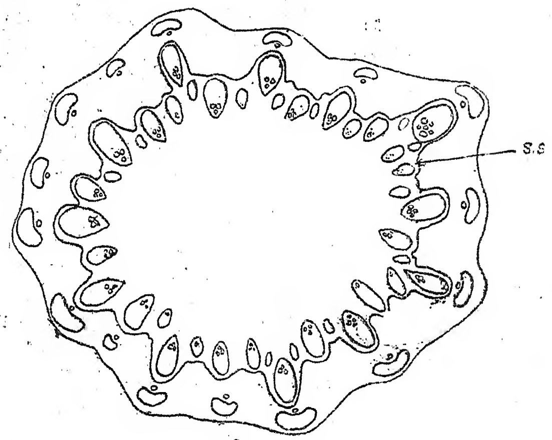

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Figs. 1–2. *Heracleum sphondylium.* Transverse sections of the stem, young and old. Fig. 1. Starch sheath as starch mantles (*S.C.*) surmounting each trace bundle. ×22·5. Fig. 2. Starch sheath (*S.S.*) as a continuous but wavy ring in a slightly older axis than in Fig. 1. *c.*, collenchyma strand ; *o.d.*, oil duct. ×30.

In most of the text-books on plant anatomy 'starch sheath' and 'endodermis' have been used synonymously. Priestley and Scott (1939) state that the cells of the starch sheath by losing their starch grains undergo a different type of development to become an endodermis

(p. 389, *cf.* also Datta, 1945). Joshi (private communication) thinks that endodermis and the starch sheath belong to the same morphological category and the latter even without the Casparian strips can be called an endodermis. In my examination of a large variety of material, although such examination was often casual, I do not remember to have seen a typical starch sheath with Casparian strips, nor have I seen a typical endodermis by subsequently losing its Casparian strips and storing starch grains in its cells becoming transformed into a starch sheath, though there are reported cases where endodermis in stem has been found to have stored starch grains (de Bary, 1884, p. 125 ; Bower, 1935, pp. 42, 44, 56).

Both starch sheath and endodermis are usually regarded as the innermost layer of cortex [Sachs[18], de Bary (1884), Strasburger (1930), Haberlandt (1914), Solereder (1908) and others], but Eames and MacDaniels (1925) describe it as the outermost layer of the stele (p. 105). Stelar endodermis has been noted in *Selaginella*,[2] *Pteris*[6] and Lycopodiaceœ.[22] The starch sheath is described as one layer thick, but in jute, *Heracleum* and *Coccinea*, at some places, it is more than one layer in thickness, whereas the endodermis has, so far as I know, never been reported to be more than one layer in thickness, nor a starch sheath has ever been reported in roots proper. In *Equisetum*,[22] however, the root lacks pericycle, and in its place an endodermis has been noticed which is two cell layers thick, the inner functioning as pericycle during the origin of secondary branches (p. 240).

Extensive works on the origin, development, structure and function of the endodermis have been done or discussed by Sachs (1875), Kroemer (1903), Mager (1907), Caspary, Schwendener (1882), Bäsecke, Bower (1920,1920), Priestley (1922, 1926), Priestley and North (1922), Isabel Soar (1922) and others ; but not much developmental work, it appears, has been done on the origin and nature of the starch sheath in the stems of vascular plants. In this paper its origin and differentiation has been followed in *Heracleum sphondylium*. The observations recorded are based on serial hand sections of the growing points mounted in iodine solution.

Observations

The starch sheath in *Heracleum sphondylium* is first differentiated in connection with each leaf-trace bundle in the foliar primordium. It forms a crescent-shaped mantle (starke-sicheln[9]) surmounting the phloem portion of each adult bundle. In its origin and development each starch mantle is differentiated from the innermost layer of 4-6 layered parenchymatous tissue developed between each vascular bundle and its associated primary oil duct. Developmental studies show that this isolated starch mantle is procambial in origin. When the leaf bundles enter the axis, the leaf being sheathing at the insertion, the trace bundles, 15–16 in number, spread around the stem in the form of a ring, and the starch sheath in the form of isolated mantles is easily followed in the stem where it is seen most characteristically associated with each leaf-trace bundle of the primordium just inserted on the axis, whereas they cannot be traced opposite the trace bundles

of the primordia of the upper leaves, these trace bundles being mostly in the desmogen stage. At this early stage, therefore, the starch sheath is procambial in origin, differentiates in association with each leaf-trace bundle and stores starch grains in its cells perhaps for the supply of formative material to the dividing and differentiating procambial cells. If a transverse section of the axis at the level of insertion of the primordium is examined in iodine solution, the starch sheath instead of forming a continuous layer round the axis appears as so many crescent-shaped mantles of the different bundles (Fig. 1). It is only at a later period that the isolated starch mantles of all the leaf-trace bundles at different depths (from the surface) in the axis join together and form a continuous but wavy sheath of the adult axis which has been noted and described by previous workers (Fig. 2).

Discussion and Conclusion

In the vascular plants we come across at least three different kinds of sheaths in three well-defined regions, *viz*., *endodermis* in roots, *starch sheath* in stems, and *parenchymatous sheath* in leaves, besides the sclerenchymatous sheath of the monocotyledon bundles. They occupy almost identical position with regard to the vascular system, *i.e.*, they limit the stele or bundles on the outside in the form of a cylindrical sheet, one layer thick and in close lateral connection of its elements. Each kind, it appears, has a definite function to discharge in its proper place, and structurally or by nature each is fitted for the purpose. Endodermis is sometimes seen to replace starch sheath in stem, or border parenchyma in the leaves. Miss Soar (1922) who made an extensive study on the structure and function of the endodermis in the leaves of Abietineæ concludes that the role of the endodermis in these leaves is contributory to the xeromorphy of that organ. The same might be said of the presence of the endodermis in the stem. Whenever a control is to be put on the lateral passage of water and solutes from the conducting region a primary endodermis is likely to develop in the region of the starch sheath in the stem. This has been well established by Datta (1945) in the transition from much branched vegetative region to the unbranched flowering axis of *Leonurus sibiricus* L.

The origin of endodermis and starch sheath also appears different. Endodermis always takes its origin in the layer of cells immediately outside the central cylinder, or the vascular bundles as the case may be. The starch sheath on the other hand, in the cases studied, invariably originates in close association with each trace bundle in the form of *stärke-sicheln* which finally unite to form the continuous layer found in the adult axis. The starch mantles, however, may not unite at all, so they remain free opposite each leaf-trace bundle, as in *Brassica oleracea*, or they store starch grains only in the cells opposite medullary rays, where two contiguous mantles meet, as seen in *Aliangene alpina*. Interrupted starch sheath in various forms has been reported by Haberlandt (1914). The endodermis is always circular in outline, but the starch sheath is wavy. This wavy nature of the starch sheath layer points to its procambial origin, as has been demonstrated in *Heracleum*.

Hence it is concluded that in the case studied no morphological value of a permanent nature can be attached to the starch sheath as a layer in the same sense as in the case of endodormis, and as such the two terms should not be used synonymously.

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SOME ABNORMAL FLOWERS OF *ANGELONIA GRANDIFLORA*

BY C. VENKATA RAO

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Received for publication on February 21, 1945

Angelonia grandiflora C. Morr. is a member of the family Scrophulariaceæ and a native of S. America. It is a common border plant in the gardens of South India and other parts of this country. The plants are generally propagated by cuttings, as the flowers ordinarily fail to produce viable seeds. The flowers are of a purplish colour. Last year, however, while visiting a local garden, the author came across some flowers of this species which, instead of being coloured, were green like the foliage leaves. On closer observation, these flowers were seen to show several abnormalities. These are briefly reported here.

The normal flowers of *Angelonia grandiflora* show the usual Scrophulariaceous structure. Fig. 1 illustrates one of them. They are borne in a solitary and axillary fashion, and possess a long slender pedicel. The calyx consists of five, free, very small sepals. Each sepal measures only about or less than two millimetres. The corolla has a short narrow tube, which expands above into a cup-shaped structure with five lobes spreading out in a bilabiate manner. The four epipetalous stamens stand towards the posterior part of the corolla. The globose ovary is topped by a short style, that does not project beyond the corolla tube.

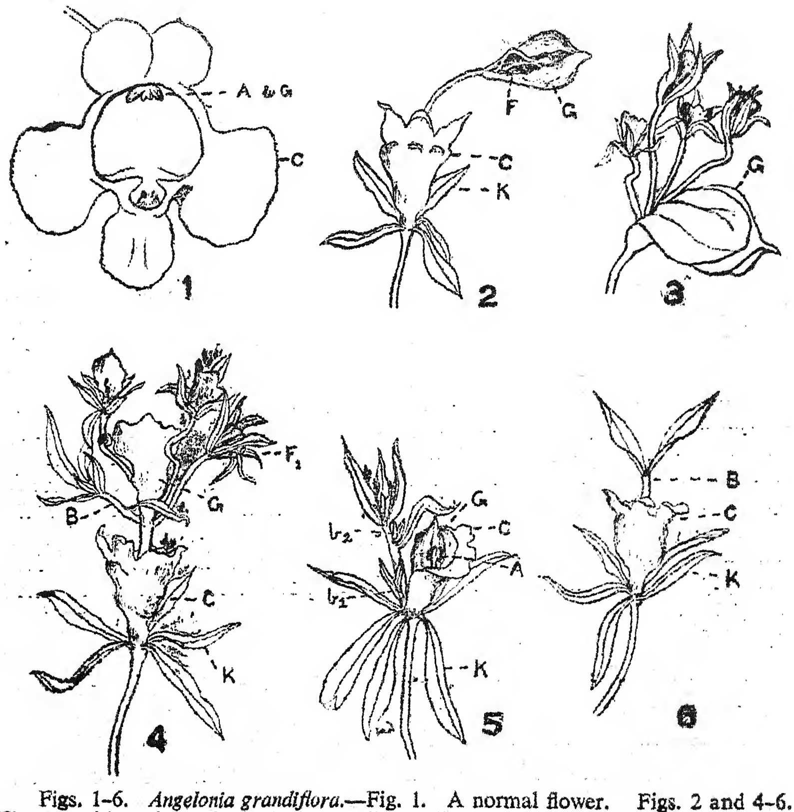
The author collected two branches bearing about forty abnormal flowers. The usual abnormalities in these flowers are :

1. A general increase in size.
2. Enlargement of the sepals into large foliaceous structures sometimes measuring up to 2 cm. in length.
3. Enlargement of the corolla tube into a longer and wider structure. Green colour of the petals.
4. Development of a long gynophore below the ovary, as recorded by Joshi (1933 and 1939) in *Argemone mexicana*.
5. Considerable increase in the size of the ovary.
6. Much proliferation.

The stamens do not appear externally to have undergone much change.

Fig. 2 illustrates a typical abnormal flower and clearly shows the abnormalities Nos. 1–5 listed above. Further, the ovary shows a small

slit on one side near the base, revealing the presence of some stalk-like structures within. On opening the ovary (Fig. 3), these are seen to be the pedicels of four flowers arising from its base. These flowers are still in the bud stage and are enclosed by the ovary wall, but as they develop, the ovary wall bursts open and they come out. This is seen in Fig. 4. Such proliferation of flowers from the ovary of a parent flower is very common and was observed in most of the flowers. Generally four



Figs. 1–6. *Angelonia grandiflora*.—Fig. 1. A normal flower. Figs. 2 and 4–6. Flowers with various kinds of abnormalities. Fig. 3. The flower shown in Fig. 2 with the ovary split open. *K*, calyx; *C*, corolla; *A*, androecium; *G*, gynœcium; *F* in Fig. 2, stalk of a flower arising inside the ovary; *Fl* in Fig. 4, a flower with seven sepals; b_1 and b_2 in Fig. 5, axillary buds on the vegetative shoot arising from the axil of the corolla of a flower; *B* in Fig. 6, the vegetative shoot arising from the apex of the thalamus in place of the gynœcium. For further explanation see text.

flowers come out of one ovary, but in some cases only two and in one case five have been noticed. In all such ovaries the septum is wanting so that the ovary becomes unilocular. In a few others which do not develop the flowers or branches inside, the ovary expands merely into a hollow structure with a thin septum but in no case were any ovules found.

Fig. 4 shows one further peculiarity. Of the four shoots coming out of the ovary, one (marked B in the figure) has developed into a vegetative branch with about 8 leaves. The other three have formed flowers. One of these flowers (F_1) shows seven sepals instead of the customary five.

Fig. 5 represents a flower showing the development of a vegetative shoot from the axil of the corolla. Such variation was observed in six flowers. The accessory shoot in Fig. 5 has eight well-developed leaves, the basal two of which already show distinct axillary buds (b_1 and b_2). No branches arise in such cases from the ovary.

Fig. 6 shows the only specimen observed in which a vegetative shoot instead of the gynœcium arises from the apex of the thalamus.

The author takes this opportunity to express his gratitude to Dr. A. C. Joshi for his help in the preparation of this note.

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GERMINATION OF THE HETEROCYST IN TWO MEMBERS OF THE RIVULARIACEÆ, *GLOEOTRICHIA RACIBORSKII* WOLOSZ. AND *RIVULARIA MANGINI* FREMY*

BY T. V. DESIKACHARY, M.SC.

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Received for publication on September 15, 1945

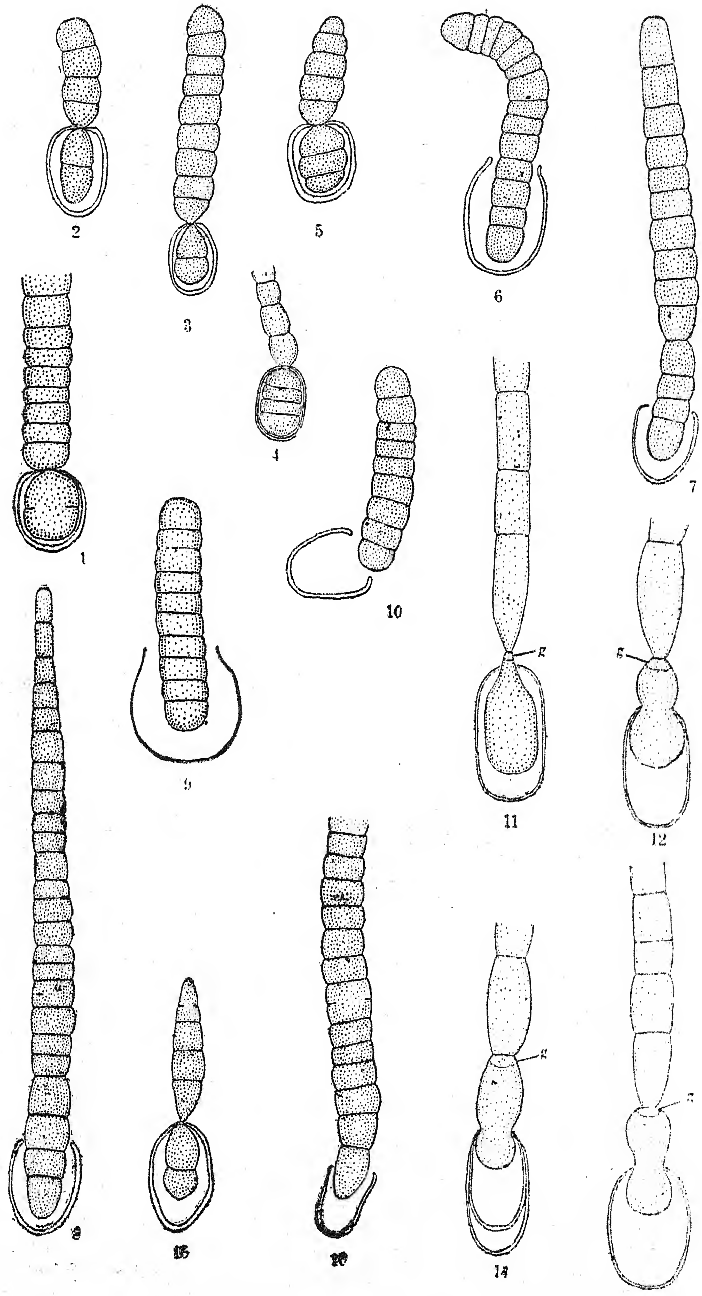
USUALLY heterocysts do not germinate. But in a few genera they have been observed to germinate. Even here it is not a very common or regular feature. Germination of the heterocyst has been recorded so far in four species of *Nostoc*, *viz.*, *N. commune* Vaucher (Geitler, 1921), *N. ellipsosporum* (Desm.) Rabenhorst (Geitler, 1921), *N. Linckia* (Roth) Bornet (Geitler, 1921) and *N. microscopicum* Carm. (Geitler, 1921), and two species of *Anabæna*, *viz.*, *A. variabilis* Kützing (Geitler, 1921) and *A. steloides* Canabæus (Canabæus, 1929), two species of *Tolypothrix*, *viz.*, *T. lanata* Wartmann (Geitler, 1921) and *T. Elenkinii* Hollerbach (Hollerbach, 1928), and one species of *Calothrix*, *viz.*, *C. Weberi* Schmidle (Steinecke, 1931). Iyengar and Desikachary (1944) have recorded a case of germination of the heterocyst in *Brachytrichia Balani* (Lloyd) Born. and Flah. Formation of gonidia by the heterocyst has been recorded by Brand (1901) in *Nostoc commune* Vaucher and *N. microscopicum* Carm. and by Spratt (1911) in *Anabæna cycadeæ* Reinke. The gonidia formed by the heterocyst later on develop into new filaments. Thus the germination of the heterocyst is known in only five genera, *viz.*, *Nostoc*, *Anabæna*, *Tolypothrix*, *Calothrix* and *Brachytrichia*. The writer came across the germinatton of the heterocyst in two genera, *viz.*, *Glœotrichia* and *Rivularia*. A detailed account of the germination is given below :—

Gloeotrichia Raciborskii Wolosz.

Glœotrichia Raciborskii was collected from a lake in Chingleput, in the month of January 1942. A portion of the material was preserved in 4% Formalin on the spot. The remaining portion of the alga was brought to the laboratory in the living condition and kept growing in the laboratory in the lake water to which some sterilized Schreiber's nutrient solution was added.

The material was vernalized several times at different temperatures ranging from 32° F. to 50° F. and for varying periods ranging from a few hours to three days, and then left at room temperature for a number of days. No heterocysts were observed to germinate for quite a long time. Finally, in one of the attempts, a number of heterocysts were

* This paper formed part of a thesis approved for the Master of Science Degree of the Madras University.



Text-figs. 1–16.—Figs. 1–14. Stages in the germination of the heterocyst in *Glœotrichia Raciborskii* Wolosz. Fig. 1. Beginning of the first division of the

contents of the heterocyst. Figs. 2 and 3. Two-celled germling stages. Fig. 4. Four-celled stage. Fig. 5. Three-celled stage. Fig. 6. A long germling that has grown out of the heterocyst. Figs. 7 and 8. Long germlings that have grown out of the heterocyst connected with the old trichome. Fig. 9. A ten-celled germling with traces of the old heterocyst wall still persisting at the base. Fig. 10. Germling fully come out of the old heterocyst wall. Figs. 11–13. Various stages of the coming out of the contents of the heterocyst without undergoing any division (g = granule). Fig. 14. Heterocyst rejuvenating for a second time. Note the two heterocyst walls. Figs. 15 and 16. Stages in the germination of the heterocyst in *Rivularia Mangini* Fremy. Figs. 1, 2, 3, 10, 15, $\times 1150$; Figs. 5–9, 16, $\times 1100$; Figs. 11–14, $\times 1450$; Fig. 4, $\times 800$.

found to have germinated. In this case the material had been exposed to a temperature of 45° F. for a period of 24 hours and then left at room temperature. This material was kept under observation and all the details of germination up to the fully developed trichome were carefully followed.

The heterocyst in the alga is situated at the base of the filament, and has a single pore on the trichome side. A large granule is present very near the pore.

Germination of the heterocyst.—The contents divide into two cells (Text-figs. 2 and 3; Pl. I, Fig. 2). The beginning of the cross-wall formation can be seen in Text-fig. 1 and Pl. I, Fig. 1; and in Text-figs. 2 and 3 and in Pl. I, Fig. 2 the division into two cells is complete. The granule present near the pore of the heterocyst evidently disappears at the commencement of the division (Text-fig. 1; Pl. I, Fig. 1). By further division of both these cells a four-celled germling is formed (Text-fig. 4; Pl. I, Fig. 3). Sometimes only one of the two cells divides and then only three cells are seen in the germling (Text-fig. 5; Pl. I, Fig. 5). As the germling grows longer and emerges out through the pore, it is seen still connected with the rest of the trichome (Text-figs. 7 and 8; Pl. I, Fig. 4). Whether, after growing further, this germling will break away from the old trichome and become an independent trichome or will continue to grow attached to the old trichome could not be definitely stated from the stages of germination available in the material. But a few cases of well grown germlings with the old heterocyst wall still persistent at the base were found in the material (Text-figs. 6, 9 and 10; Pl. I, Fig. 6). These well grown germlings were quite independent and were not connected with the old trichome portions. These germlings might have broken away from the old trichome or might merely be the product of the germination of isolated heterocysts.

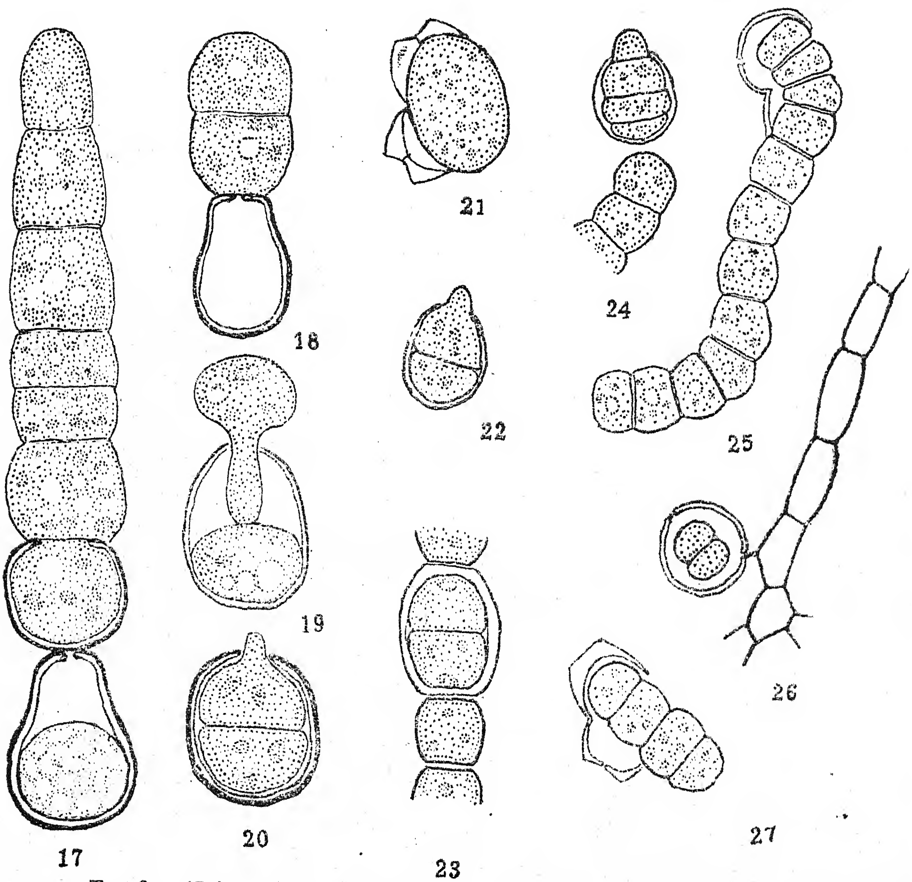
During the germination of the heterocyst the inner cellulose layer of the heterocyst wall is the first to be dissolved and the outer layer gets dissolved away later on. This outer layer is generally seen persisting for quite a long time at the base of the germling trichome (Text-figs. 7–10).

In the living material which was brought to the laboratory the entire contents of the heterocysts were sometimes observed to come out of the heterocyst wall gradually without undergoing any division (Text-figs. 11, 12 and 13) and were still connected with the rest of the trichome. The contents which have come out of the old wall secrete

a new wall and become a heterocyst again. This evidently represents only a case of rejuvenation of the contents of the heterocyst and not of germination. In one case the contents of the heterocyst have rejuvenated twice. After coming out of the wall a short distance the contents evidently surrounded itself with a new wall and was coming out of the new wall again (Text-fig. 14 ; Pl. I, Fig. 7).

Rivularia Mangini Fremy

This alga was collected on moist rocks near a waterfall at Tirupati in South India. This collection which was preserved in 4% formalin on the spot proved interesting since a few germinating heterocysts were found in it. As in the case of *Glœotrichia* described above, a two-celled germling was found enclosed inside the heterocyst wall (Text-fig. 15 ; Pl. I, Fig. 8). The three-celled or four-celled germling



Text-figs. 17–27.—Figs. 17–20. Stages in the germination of the heterocyst in *Calothrix Weberi* Schmidle (after Steinecke). ×1900. Figs. 21–25 and 27. Stages in the germination of the heterocyst in *Nostoc commune* Vaucher (after Geitler). Fig. 26. A two-celled germling in a heterocyst in *Brachytrichia Balani* (Lloyd) Born. and Flah. (after Iyengar and Desikachary).

stages were not found in the material. But a few long germlings were found with traces of the old heterocyst wall still persisting as a cap at the base. These are cases of germination of the heterocyst under natural conditions, since the material was not treated in any way in the laboratory but was preserved as soon as collected. The germination of the heterocyst in *Brachytrichia Balani* recorded by Iyengar and Desikachary (1944, p. 46, Fig. 7 *i*) was also a case of germination under natural conditions (Text-fig. 26).

Discussion

Geitler (1921), Hollerbach (1928), Canabæus (1929) and Steinecke (1931) have recorded the germination of the heterocysts in several blue-green algæ. In all these cases they found that the contents by a series of transverse divisions became a germling. In most of these cases only a few divisions of the contents were followed. But all the various stages of germination of the contents and the development of the germling into long filaments appears to have been followed so far only in three members of the Cyanophyceæ, *viz*., *Nostoc commune* (Geitler, 1921), *Tolypothrix Elenkinii* (Hollerbach, 1928) and *Calothrix Weberi* (Steinecke, 1931).

According to Geitler in *Nostoc commune* the contents of the heterocyst first divide to form a two-celled germling (Text-figs. 22 and 23) which by further division becomes a four-celled germling (Text-figs. 24 and 27). This four-celled germling becomes free either through a circumcissal break of the heterocyst wall at the middle into two pieces (Text-figs. 25 and 27) or comes out through one of the pores (Text-figs. 22 and 24). The germling after coming out, by further division, grows into a filament.

The stages of germination of the heterocyst in *Calothrix Weberi* (Text-figs. 17–20) as recorded by Steinecke (1931) are somewhat different from those recorded by Geitler in *Nostoc commune*. The contents of the heterocyst in *Calothrix Weberi* by a transverse division form a two-celled germling (Text-fig. 20). The cell close to the pore of the heterocyst squeezes itself out of the heterocyst wall through the pore (Text-figs. 19 and 20) and then by further divisions gradually grows into a mature filament (Text-fig. 17). The second cell which remains inside degenerates (Text-figs. 17 and 19).

In the two algæ dealt with in this paper not even a single case was observed of the emerging out of the upper cell to form a new filament and the degeneration of the lower cell as recorded by Steinecke (1931) in *Calothrix Weberi*. The writer's observations on the germination of the heterocyst in *Glœotrichia Raciborskii* agree closely with those of Geitler on *Nostoc commune*. But the germling in *Gl. Raciborskii* does not emerge from the heterocyst wall through a break in the middle, but emerges out of the heterocyst wall always through the widening of the pore.

Finally no case of godidia formation by the heterocyst as recorded by Brand and Spratt was observed in the two present algæ.

Summary

Germination of the heterocysts has been known only in five genera, *viz.*, *Nostoc*, *Anabæna*, *Tolypothrix*, *Calothrix* and *Brachytrichia*. The germination of the heterocyst in two more genera, *viz.*, *Glœotrichia* (*Gl. Raciborskii*) and *Rivularia* (*R. Mangini*) is described in the paper.

The details of germination agree closely with those recorded by Geitler in *Nostoc commune*. The stages of germination of the heterocyst described by Steinecke in *Calothrix Weberi, viz.*, the emerging out of the upper cell of the two-celled germling and the degeneration of the lower cell, were not observed in the forms investigated here.

The author wishes to express his great indebtedness to Prof. M. O. P. Iyengar, M.A., Ph.D. (Lond.), F.L.S., for his constant guidance and help during the course of this investigation and in the preparation of this paper. His sincere thanks are also due to the authorities of the University of Madras for the award of a research scholarship during the tenure of which the present investigation was carried out.

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EXPLANATION OF THE PLATE

Figs. 1–7. Stages in the germination of the heterocyst in *Glœotrichia Raciborskii* Wolosz.

Fig. 1. The beginning of the division of the contents of the heterocyst.

Fig. 2. Two-celled germling.

Fig. 3. Four-celled germling.

Fig. 4. A germling with traces of the heterocyst wall still present at the base growing still connected with the old trichome.

Fig. 5. Three-celled germling.

Fig. 6. A well-grown germling with the heterocyst wall covering the base.

Fig. 7. Heterocyst rejuvenating for a second time. Note the two heterocyst walls.

Fig. 8. A two-celled germling surrounded by a brownish mucilage in *Rivularia Mangini* Fremy.

(Figs. 1, 5, 7, ×1900; Figs. 2, 3, ×1200; Fig. 4, ×1100; Figs. 6, 8, ×1650.)

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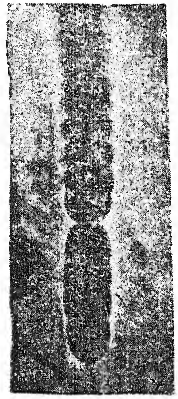

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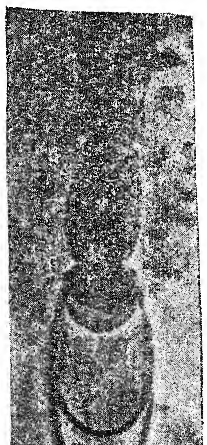

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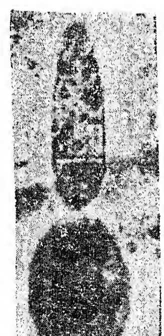

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T. V. DESIKACHARY—

GERMINATION OF THE HETEROCYST IN GLŒOTRICHIA RACIBORSKII *WOLOSZ. AND* RIVULARIA MANGINI *FREMY*

NUCLEAR DIVISION IN *SPIROGYRA**

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Introduction

The details of nuclear division in such a common alga as *Spirogyra* have formed the subject of repeated study by various workers. Strasburger (1875) was the first to investigate the process in the alga. Since then there has been quite a lot of discussion on the matter, the main points of discussion being the nature of the nucleolus and the origin of the chromosomes. A summary of the work done by the earlier workers on mitosis in *Spirogyra* is given by Mitzkewitsch (1898), Lutman (1911) and Wisselingh (1921).

Three views have been put forward so far, *viz.*, (1) that all the chromatin material is lodged in the nucleolus and that the chromosomes therefore take their origin from the nucleolus (Strasburger, 1875; Tangl, 1882; Moll, 1893; Mitzkewitsch, 1898; and Berghs, 1906), (2) that the chromosomes are derived partly from the nucleolus and partly from the reticulum (Strasburger, 1882; Flemming, 1882; and Wisselingh, 1900, 1902, 1921) and (3) that the chromosomes do not originate from the nucleolus at all, but are derived solely from the reticulum (outer nucleus) (Strasburger, 1888; Degagny, 1894; Geitler, 1930, 1935 *a*, *b*; and Suematsu, 1936).

Strasburger (1875), from his investigation of the nuclear division in *Spirogyra orthospira*, stated that the nucleolus divides into a number of bodies which arrange themselves into an equatorial plate. But, later on in 1882 (pp. 162–75), after examining the nuclear division in *Spirogyra majuscula*, he modified his earlier view and stated that the nucleus has got a reticulum which forms the equatorial plate with the help of the substance of the nucleolus. Later on in 1888, after working on *S. polytæniata*, he changed his view still further and stated that the reticulum alone takes part in the formation of the chromosomes as in the higher plants.

Flemming (1882) considered that the nucleolus together with the reticulum contributes the material for the construction of the equatorial plate. The reticulum according to him contains an extremely meagre quantity of chromatin as compared with the large amount in the nucleolus.

Tangl (1882), Moll (1893) and Mitzkewitsch (1898) expressed the opinion that the equatorial plate is formed at the expense of the substance of the nucleolus which consists of both linin and chromatin.

* From the University Botany Laboratorv, Madras.

Meunier (1887) thought that the nucleolus contained all the chromatin and furnished the necessary material for the formation of the equatorial plate. He described the nucleolus as having an unbroken thread-like structure inside and stated that it possessed all the properties of the nucleus of other plants. He called the nucleolus a "*noyau en miniature*".

Degagny (1894–96) states that the equatorial plate is formed from the reticulum which at the beginning of mitosis closely envelops the nucleolus and the substance of the nucleolus passes into it.

Wisselingh (1900, 1902, 1921) states that the chromatin material is found both in the nucleolus and in the reticulum. By a progressive digestion of the nucleus in 40% chromic acid, he comes to the conclusion that two chromosomes arise from the nucleolus and the remaining ones from the reticulum.

Berghs (1906) states that twelve chromosomes arise from the nucleolus, the reticulum being quite free from it. In the nucleolus a second substance still remains which stains feebly and divides into two parts which move to the poles along with the chromosomes.

Merriman (1913) describes a spireme originating from the material derived from both the nucleolus and the reticulum. This spireme, she states, consists of a granular substance derived from the nucleolus and a filamentous material from the nuclear network. She later on, in 1916, however, states that the nucleolus does not fragment directly into chromosomes, but only contributes to the less dense substance seen at metaphase. She expresses the view that *Spirogyra* as regards the constitution and behaviour of its nucleolus need not be placed in a different category from the other green algæ or from the higher plants.

Stolley (1930) states that dark granular or thread-like structures appear in the outer nucleus, while the nucleolus is still intact, and that these structures are seen at the periphery of the nucleolus as it begins to break up. She thinks that it is probable that they are derived from the outer nucleus (reticulum) and get imbedded later on in the nucleolar substance. She considers these bodies as chromosomes and doubts whether the substance in which they are found could still be called the nucleolus. She states that a study of their chemical nature is necessary to decide their origin.

Geitler (1930) investigated three species of *Spirogyra* and found that the chromosomes in each of them are fully formed in the outer nucleus (the reticulum), while the nucleolus is still intact. He thinks that the chromosomes in the outer nucleus are masked by some substance for some time and become visible only later on. The duration of masking, however, is not the same in all species. He states that the mistaken view of the earlier authors that the chromosomes originate from the nucleolus is evidently due to this. Later on he (Geitler, 1935 *a*) investigated one more species (*Spirogyra X*) and confirmed his earlier view that the chromosomes arise in the 'outer nucleus' quite independently of the nucleolus. In the same year he (1935 *b*) investigated a number of other species by using Feulgen stain

and found that in every case the nucleolus in the resting nucleus remained unstained, while in the outer nucleus were found several deeply stained granules which he considered were probably chromocentres. The chromosomes, which are organised a little later in the outer nucleus, also show a positive reaction to the stain, while the nucleolus, which is still intact, shows a negative reaction. He comes to the conclusion that the chromosomes arise only from the reticulum and that the nucleolus does not contribute anything to their formation and finally expresses the view that the nucleus in *Spirogyra* is quite similar in structure and substance to that of the higher plants.

Conard (1933, 1939) states that the chromosomes are found in the outer nucleus and that the nucleolus breaks up into a granular mass which becomes a thick disc-like mass in which the chromosomes are found imbedded during metaphase.

Suematsu (1936) states that the nucleus of *Spirogyra* resembles that of the higher plants, that the chromatic granules appearing in the outer nucleus give rise to the chromosomes and that the chromosomes throughout the process of mitosis show a positive reaction to Feulgen stain.

In view of the different views expressed regarding the origin of the chromosomes, a detailed investigation of the nuclear division was taken up in a few species of *Spirogyra* occurring in Madras in order to find out how far the results obtained by the writer agreed with, or differed from, those obtained by the previous workers.

Material and Methods

Four species of *Spirogyra* were taken up for investigation, *viz.*, *S. columbiana* Czurda, *S. Fuellibornei* Schmidle, *S. paraguayensis* Borge and *Spirogyra* sp. Of these, *Spirogyra columbiana* and *S.* sp. were growing in a water drain near the laboratory, *S. Fuellibornei* in a temporary pool in the Madras beach and *S. paraguayensis* in a pond inside the Madras Museum compound. The material was fixed at intervals of half an hour during the course of twenty-four hours. The most abundant division figures were obtained in material fixed between 11 p.m. and 1 a.m.

The following fixing fluids were tried:—Flemming's weak, Flemming's strong, Flemming's strong diluted with an equal amount of water, Nawaschin's fluid, Chamberlain's chromo-osmo-acetic mixtures, Schaudinn's sublimate-acetic alcohol and Bouin's fluid as modified by Allen (P.F.A_3). Of these, Bouin's fluid and Nawaschin's fluid gave the best results.

The material fixed in Nawaschin's fluid was washed in running water for six to eight hours and then taken up through the alcohol grades to 70% alcohol. And the material fixed in Schaudinn's solution was washed in 50% alcohol until it was quite free from mercuric chloride, and then taken up to 70% alcohol.

For imbedding in paraffin the following procedure was adopted. A small bunch of the filaments in 70% alcohol was taken up by one

end with a pair of forceps, when the filaments hang down more or less parallel to one another. Small lengths of this bunch of filaments were cut with a pair of scissors and rolled up in a small piece of lens-paper. These tiny lens-paper rolls with the material inside were treated as whole materials and passed through the alcohol and the xylol grades and finally infiltrated in paraffin. After infiltration, the lens-paper was carefully removed from the bundle of filaments inside with the aid of hot needles and the material was finally imbedded. Sections 5–10 μ thick were cut with the aid of a Spencer rotary microtome.

Whole-mount-preparations in Venetian turpentine (Chamberlain, 1933, p. 106) and in Canada balsam (McClung, 1937, pp. 202–03) were also made from material in 70% alcohol. The sections, as well as the whole-mount-material, were stained in Heidenhain's iron-alum hæmatoxylin. One species, *S. Fuellibornei*, was stained in Feulgen stain also. For this purpose, the material in 70% alcohol was taken down to water and washed thoroughly, rinsed in distilled water and hydrolysed in N.HCl at 60° C. for about 6–10 minutes, then rinsed two or three times in cold N.HCl and finally in distilled water before tranfserring to the stain, where it was kept for 6 hours to overnight. The stained material was not washed in sulphurous acid, as the latter destained it very rapidly.

Spirogyra columbiana Czurda

The resting nucleus.—The resting nucleus in this species is elliptic to spherical in shape (Text-fig. 1). It has a large darkly staining nucleolus with a crisp outline. The outer nucleus is occupied by a faintly stained delicate reticulum. The nucleolus shows one or more vacuoles inside it (Text-fig. 1 ; Pl. II, Fig. 3).

Prophase.—At the beginning of the prophase, the nucleus enlarges slightly and becomes elongated along the length of the cell. The nucleolus is still quite intact and shows a sharp outline. Darkly staining granules are seen in the outer nucleus in the meshes of the reticulum (Text-fig. 3). At this stage the nucleolus becomes somewhat irregular in shape and loses its outline. At a slightly later stage, short rod-like chromosomes are seen scattered in the outer nucleus (Text-fig. 4). The surface of the nucleolus appears somewhat broken up. At a still later stage the nucleolus completely loses its sharp outline and becomes a granular mass, and some of the rod-like chromosomes appear with their ends half immersed inside the nucleolar substance (Text-fig. 5). The chromosomes are found later on completely imbedded inside the greyish granular nucleolar substance. Each of these chromosomes is surrounded by a thin hyaline outer portion. This hyaline area is seen very clearly round the chromosomes which are imbedded in the greyish nucleolar substance (Text-fig. 6).

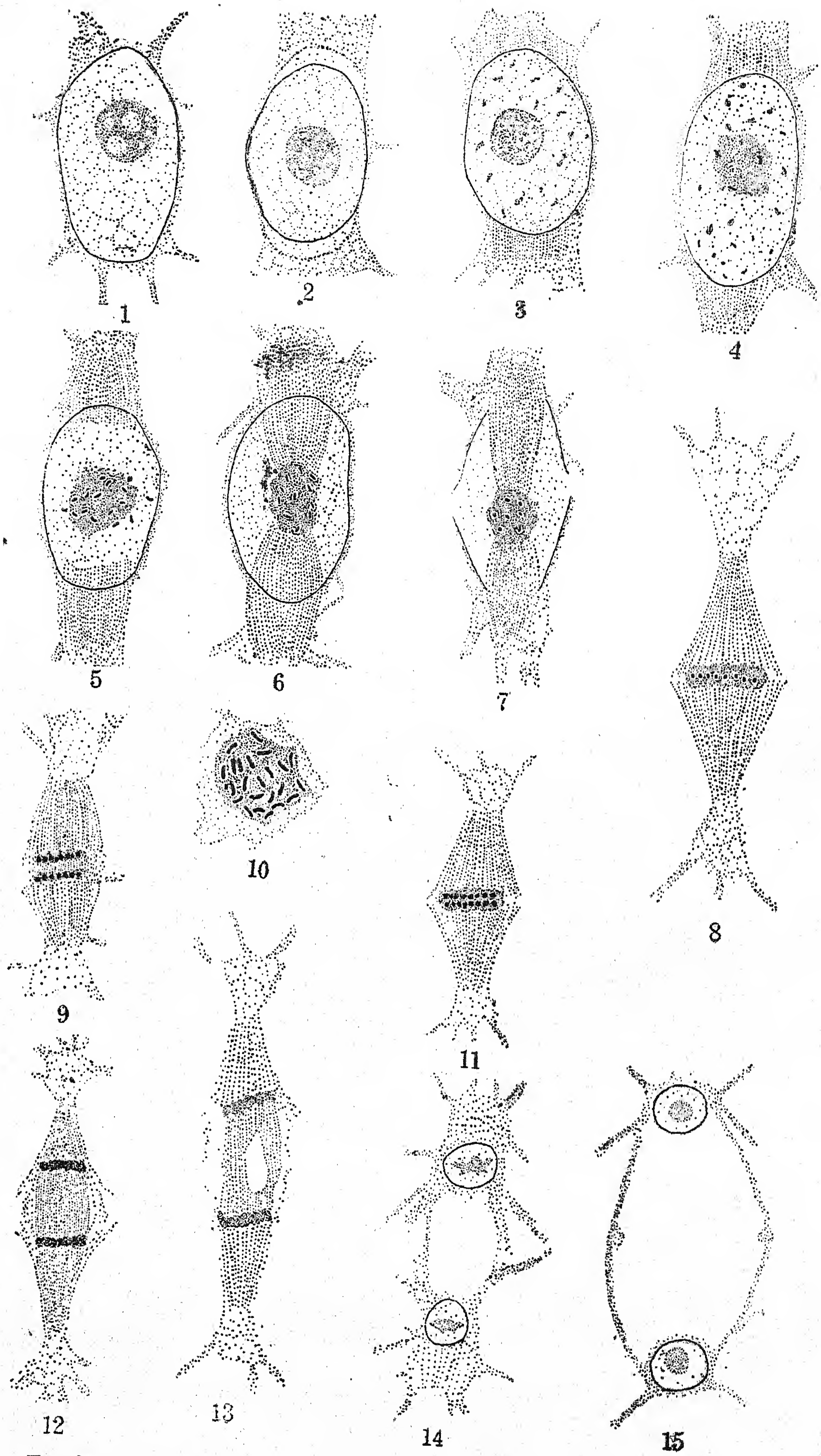
At the beginning of the prophase, a dense cytoplasmic accumulation is seen at each polar region of the nucleus (Text-fig. 2). This accumulation is at first spongy, but later on a definite transparent region could be seen between the nuclear membrane and the rest of the cytoplasm at each end of the nucleus. These two transparent

regions are crescent-shaped and appear to be the polar caps (Text fig. 2). A little later, striations which are very delicate and parallel to one another, appear in these polar caps and extend outwards and away from the nuclear membrane (Text-fig. 3). McAllister (1931, p. 840) found that the nuclear membrane in *S. setiformis* at this stage is depressed at the polar regions. He states that Berghs (1906) interprets it as due to the pushing action of the fibres of the caps. No such depression was seen at the polar regions in the present alga. After this stage the striations gradually extend inside the nucleus (Text-fig. 5), and as they approach the nucleolar mass, converge a little and become finally closely attached to the nucleolar mass (Text-fig. 6). The fibres outside the poles of the nucleus are now longer than before showing that they have extended still further into the cytoplasm. The nuclear membrane then appears to break down at the two poles at the region of the exit of the striations. At this stage, in median optical section, the nuclear membrane is completely absent at the poles, though it is still quite distinctly visible in the remaining portions. After sometime the nuclear membrane becomes broken up at the sides also, the break starting first at the equatorial region (Text-fig. 7). At this stage the nuclear figure is quite long with the spindle fibres well developed. The facts detailed above would appear to suggest that the spindle fibres originate in the cytoplasm of the polar cap portion and then extend into the nuclear cavity.

Metaphase.—The nucleolar substance with the chromosomes inside it becomes flattened and assumes the form of an equatorial plate in which the chromosomes are arranged very regularly (Text-fig. 8). The nucleolar substance stains grey with iron-alum hæmatoxylin, while the chromosomes take up a dark stain. In polar view of the plate, the chromosomes appear rod-shaped and are closely arranged. The thin hyaline area mentioned already is seen round each chromosome (Text-figs. 8, 9). The number of chromosomes seen in polar views of the metaphase plate obtained in transverse sections of the filaments is 24 (Text-fig. 9). By this time the nuclear membrane completely disappears and no trace of it is seen either in the polar or side view of the spindle.

Some of the outer fibres of the spindle at this stage, are seen broken at the equatorial region (Text-fig. 8), while the remaining ones are continuous. The spindle fibres converge towards the pole. They do not, however, meet at a single point, but end in a more or less round cytoplasmic aggregation from which strands of cytoplasm radiate outwards (Text-figs. 8, 9, 11, 12). The main central portion of the aggregation is somewhat diffuse and does not take up much stain. A few darkly stained granules are seen inside it. These polar cytoplasmic aggregations show a distant resemblance to asters of a nuclear spindle, but no centrosomes are seen in them.

Anaphase.—At the beginning of anaphase the chromosomes divide and are arranged in two parallel rows within the nucleolar matrix (Text-fig. 11). The nucleolar plate then splits transversely into two, and the two plates, each with its own set of daughter-chromosomes imbedded in it, soon separate and begin to move towards the poles of



Text-figs. 1–15. *Spirogyra columbiana* Czurda.—Fig. 1. Resting nucleus. Note vacuoles inside the nucleolus. Fig. 2. Polar caps formed at the two poles

of the nucleus. Fig. 3. Chromosomes originating in the outer nucleus. Note the nucleolus still intact with a regular outline; striations developed in the polar cap region. Fig. 4. Chromosomes distributed in outer nucleus and the outline of the nucleolus already broken. Fig. 5. Most of the chromosomes imbedded in the nucleolar mass with a few still outside. Note the spindle fibres extending into the nuclear cavity from the polar regions. Fig. 6. Late prophase. All the chromosomes imbedded in the nucleolar substance and the spindle fibres extended up to the nucleolar mass. Nuclear membrane still intact. Note the hyaline area round the chromosomes imbedded in the nucleolar substance. Fig. 7. Late prophase. The nuclear membrane broken at the polar regions and also at the equatorial regions. Fig. 8. Metaphase. Note the cytoplasmic accumulation outside the poles of the spindle. Fig. 9. Early anaphase. The nucleolar substance divided into two plates. Fig. 10. Polar view of metaphase. 24 Chromosomes seen inside the nucleolar mass, each with a thin hyaline portion round it (from microtome section). Fig. 11. Early anaphase. Two rows of chromosomes within a common matrix of nucleolar substance. Fig. 12. Late anaphase. Fig. 13. Later stage with vacuole developed inside the spindle. Fig. 14. Telophase. Fig. 15. Daughter nuclei organised. Figs. 14 and 15, ×780; the rest, ×1150.

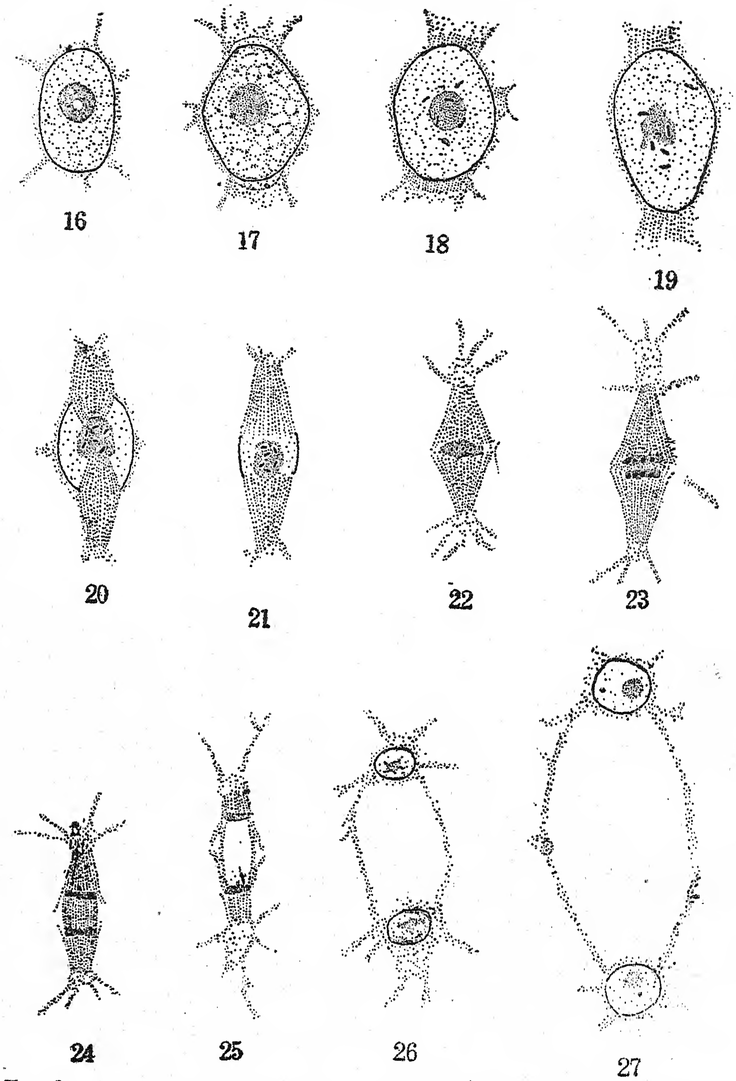
the spindle (Text-fig. 9). The hyaline space which was seen round each chromosome during late prophase and metaphase (Text-figs. 5–8, 10) is not seen during anaphase (Text-figs. 9, 11). The chromosomes at the same time appear thicker than during the previous stages (Text-fig. 11). The disappearance of the hyaline space round each chromosome and the sudden increase in the thickness of the chromosomes suggest that the hyaline area very probably represents some portion of the chromosomes which is not chromatic during prophase and metaphase, but becomes chromatic at the beginning of anaphase and takes up the stain with the result that the chromosome appears thicker and without any hyaline space round it. The two daughter plates then move still further towards the poles; and at late anaphase the plates still remain flat but the whole plate becomes darker and the distinction between the darkly staining chromosomes and the grey nucleolar substance is soon lost (Text-figs. 12, 13).

Telophase.—At the beginning of telophase the daughter plates become compressed laterally and appear somewhat twisted (Text-fig. 14). The nucleolus appears later (Text-fig. 15), but its exact origin could not be determined.

Spirogyra SP.

The resting nucleus has a prominent nucleolus and a faintly staining reticulum (Text-fig. 16). A number of vacuoles of varying sizes is seen inside the nucleolus.

Prophase.—At the beginning of prophase, the nucleus enlarges and darkly stained granules become prominent at the corners of the meshes of the reticulum (Text-fig. 17). At a later stage, six short thread-like structures are seen in the outer-nucleus (Text-fig. 18). At this stage the nucleolus is still quite intact. At a still later stage, its outline becomes slightly broken up and the vacuoles are no longer seen inside it. The nucleolus then disintegrates into a mass of granular substance. The thread-like structures become condensed into short thick darkly stained chromosomes. These chromosomes are seen crowded round the nucleolar substance and later on to



Text-figs. 16–27. *Spirogyra* sp.—Fig. 16. Resting nucleus. Note the vacuoles inside the nucleolus. Fig. 17. Early prophase. Chromatic granules seen in the outer nucleus. Polar caps formed in the cytoplasm at the poles of the nucleus. Fig. 18. Six chromosomes fully organised in the outer nucleus and gathered round the nucleolus which is still intact. Spindle fibres developed in the cytoplasm at the poles. Fig. 19. Chromosomes entering the disintegrated nucleolar substance. Fig. 20. Late prophase with all the chromosomes imbedded in the nucleolar substance and the spindle extended upto the nucleolar mass; nuclear membrane broken through at the poles, but still intact at the sides. Note the hyaline portions round the chromosomes in Figs. 20–22. Fig. 21. Later stage showing the disappearance of the nuclear membrane. Fig. 22. Metaphase. Fig. 23. Early anaphase. Figs. 24 and 25. Later stages of anaphase. Fig. 26. Telophase. Fig. 27. Daughter nuclei organised. Note the extra body beside the nucleolus in the daughter nuclei. All figs., ×1150.

enter it (Text-fig. 19). At the next stage the six chromosomes are seen completely imbedded inside the nucleolar substance. Each of the chromosomes inside the granular nucleolar substance is surrounded by a narrow hyaline area as in the previous species (Text-fig. 20).

During all these stages there takes place an accumulation of cytoplasm at the poles of the nucleus constituting the polar caps. These are thinner than in *S. columbiana* (Text-fig. 17). Later, striations are developed in this cytoplasm of the polar caps and these extend into the nuclear cavity (Text-fig. 20). The nuclear membrane first becomes ruptured in the polar region as in the previous species (Text-fig. 21). The spindle is thus seen to be extranuclear and cytoplasmic in origin.

Metaphase.—The nucleolar mass becomes spread out laterally with the imbedded chromosomes arranged more or less in a plate (Text-fig. 22). The chromosomes still show the narrow hyaline areas around them. The nuclear membrane is not present at this stage.

The spindle is broadest at the equator and narrowest at the poles and, at each end of the spindle is seen a mass of diffuse cytoplasm which is faintly granular.

Anaphase.—The chromosomes and the nucleolar mass divide into two plate-like masses each with one set of daughter chromosomes inside (Text-fig. 23). These two masses move garadually towards the poles. The chromosomes at this stage do not show the hyaline areas around them, but appear thicker. A little later the chromosomes become indistinguishable from the surrounding nuclear substance which becomes more deeply stained (Text-figs. 24, 25). Vacuoles are developed inside the spindle. These vacuoles enlarge and gradually unite with one another and finally form a single large vacuole inside. The vacuole increases in size and, as a result, the spindle becomes more and more distended and barrel-shaped.

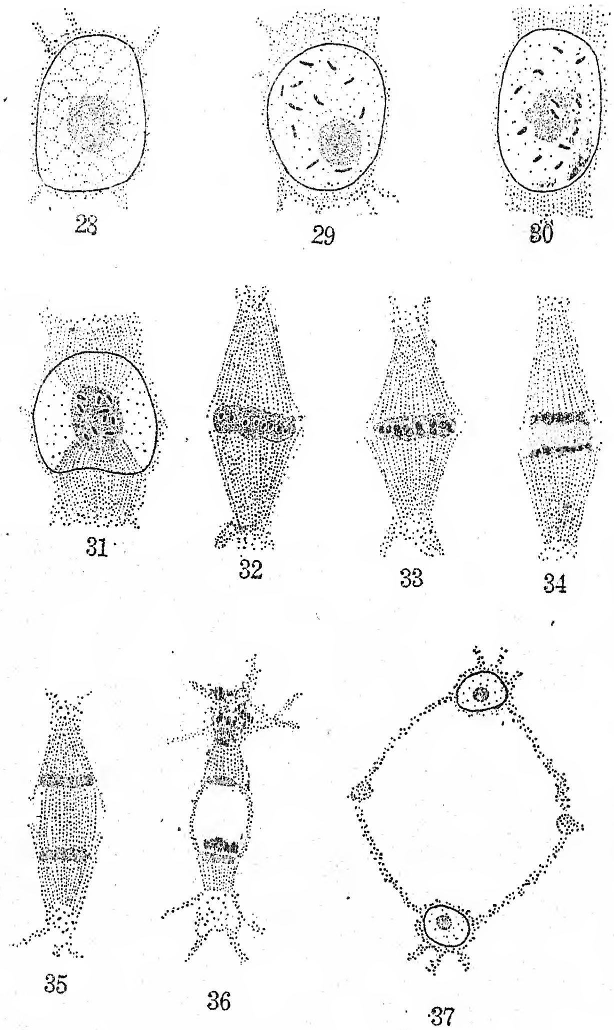
Telophase.—The flat plates of the anaphase get gradually organised into the daughter nuclei each with a nucleolus (Text-fig. 26).

In the young daughter nuclei was sometimes seen a small dark body besides the nucleolus, somewhat resembling the "*Nebenkorper*" described by Czurda (1922) in *Spirogyra setiformis*. This was not seen in any other stages.

Spirogyra Fuellibornei SCHMIDLE

The resting nucleus.—The resting nucleus has a large nucleolus with one or more vacuoles inside (Text-fig. 28). The stages of the nuclear division are very similar to those of *S. columbiana* described previously.

Prophase.—The nucleus enlarges a little at the beginning of prophase. During early prophase twelve slender slightly elongated thread-like chromosomes could be seen distributed in the outer nucleus



Text-figs. 28–37. *Spirogyra Fuellibornei* Schmidle.—Fig. 28. Resting nucleus with a large nucleolus having vacuoles inside. Fig. 29. Twelve long chromosomes seen in the outer nucleus. Nucleolus quite intact. Fig. 30. Chromosomes condensed; nucleolus beginning to break up. Fig. 31. Late prophase. All the chromosomes imbedded in the nucleolar mass. Note the hyaline region in Figs. 31 and 32. Fig. 32. Metaphase. Fig. 33. Early anaphase. Chromosomes just dividing. Figs. 34–36. Later stages of anaphase. Fig. 37. Daughter nuclei organised. Fig. 37, ×780; the rest, ×1150.

(Text-fig. 29). The chromosomes of this species are longer than those of the two previous species. At the stage when the chromosomes become organised, the nucleolus is quite intact and shows a regular

outline. At a later stage, the chromosomes crowd round the nucleolus, which by this time loses its crisp outline. The nucleolus then disintegrates into a mass of granular substance. The chromosomes then enter inside the nucleolar substance. In Text-fig. 30, which represents this stage, two of the chromosomes have already entered inside the nucleolar substance. Finally all the chromosomes are found imbedded in the nucleolar substance, and each of the chromosomes has a hyaline area round it (Text-fig. 31).

The spindle is formed in the same manner as in the two previous species, and starts in the cytoplasm of the polar caps and extends into the nucleus. The polar caps are much thinner in this species (Text-fig. 29) than in the previous species.

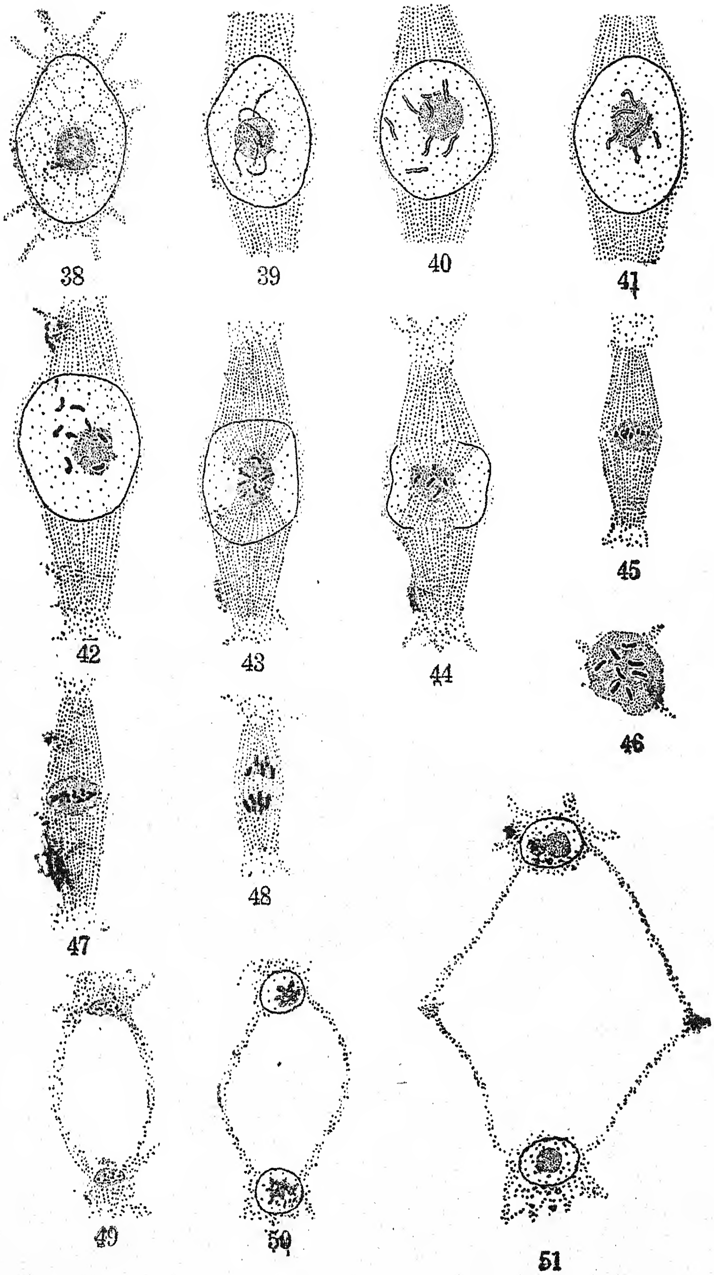
Metaphase.—The nucleolar substance with the chromosomes imbedded in it forms the equatorial plate (Text-fig. 32). Each chromosome still shows the hyaline area around it.

As in the previous forms, here also the cytoplasmic masses are seen outside the polar region of the spindle.

Anaphase.—The beginning of the anaphase is indicated by the division of the chromosomes (Text-fig. 33). The hyaline area round the chromosomes disappears and the chromosomes appear thicker. The nucleolar plate and the chromosomes inside it divide and the daughter plates move polewards. As in the other forms the daughter plates in late anaphase appear as a single mass, the distinction between the chromosomes and the nucleolar substance being lost (Text-figs. 35, 36).

Telophase.—The daughter nuclei are formed in the same way as in *S. columbiana*. A second body besides the nucleolus which was occasionally seen in *S.* sp. was not observed in this species at any time.

The material of this species was stained in Feulgen's stain also to find out how far the nucleolus could be considered as chromatic in nature. The following observations were made with material stained in Feulgen's stain. The resting nucleus remains unstained. But the slightly enlarged nucleus (just before prophase) shows a number of stained granules in the outer nucleus, while the nucleolus remains unstained. During late prophase, the chromosomes are clearly stained in the reticulum area (outer nucleus), while the nucleolus which is quite intact, remains unstained. This clearly proves that the chromatic material is found in the reticulum area and not in the nucleolus. During metaphase the chromosomes are stained red, while the nucleolar matter is not stained at all. During anaphase, when the chromosomes and the nucleolar substance become indistinguishable, the whole plate takes on a light red stain. Thus throughout nuclear division, the chromosomes show a positive reaction to Feulgen's stain, while the nucleolus shows a negative reaction. This chemical evidence clearly shows that the chromosomes are not derived from the nucleolus. These observations fully agree with those of Geitler (1935 *a*, p. 13 ; 1935 *b*, p. 274) and of Suematsu (1936, p. 38).



Text-figs. 38–51. *Spirogyra paraguayensis* Borge.—Fig. 38. Resting nucleus: vacuoles seen inside the nucleolus. Fig. 39. Early prophase showing long thread-like structures in the outer nucleus. Figs. 40 and 41. The thread-like structures

condensed into long chromosomes. Note the longitudinally split appearance of the chromosomes; the nucleolus still intact. Fig. 42. Mid-prophase; the chromosomes further condensed and with the split appearance lost; nucleolus breaking up and some chromosomes seen entering it. Eight chromosomes are seen. Figs. 43 and 44. Late prophase. Chromosomes already entered into the nucleolar substance; spindle extended upto the nucleolar mass. Fig. 45. Metaphase. Fig. 46. Polar view of metaphase showing eight chromosomes. Fig. 47. Early anaphase showing the chromosomes dividing. Note the hyaline area round the chromosomes imbedded in nucleolar substance in Figs. 42–46. Fig. 48. Mid-anaphase, note the thickened chromosomes and the absence of the hyaline area round them. Fig. 49. Early telophase. Fig. 50. Late telophase showing the stellate mass inside the daughter nuclei. Fig. 51. Daughter nuclei organised. All figs., ×1050.

Spirogyra paraguayensis Borge

The resting nucleus.—The resting nucleus as in the other species contains a large nucleolus. The nucleolus often contains one or more vacuoles inside it. The outer nucleus appears quite clear (Text-fig. 38).

Prophase.—At the approach of prophase, cytoplasm accumulates at the polar regions of the nucleus. In the outer nucleus there appear long slender thread-like structures, which are much longer than those met with at this stage in the three previous species (Text-fig. 39). These thread-like chromosomes become more definite at a later stage, when they take up stain more deeply. The chromosomes in this species are larger than those of the previous ones and show more details in their structure. They appear to be split longitudinally (Text-figs. 40, 41). The nucleolus is homogeneous at this stage, but still shows its original regular outline. The long chromosomes later on contract a little and approach the nucleolus and are later on seen very close to it. The nucleolus then begins to lose its sharp outline and shape, and becomes disintegrated into a mass of granular substance. Some of the chromosomes could be seen at this stage having one of their ends in intimate contact with the nucleolus appearing as though entering into it (Text-fig. 42; Pl. I, Fig. 15). Eight chromosomes could be counted at this stage. Finally in late prophase all the chromosomes are found completely imbedded inside the nucleolar substance (Text-figs. 43, 44). In this alga also a hyaline area is seen round each chromosome.

The spindle is formed in the same way as in the other species, and starts in the cytoplasm of the polar caps and extends into the nuclear cavity (Text-figs. 43, 44).

Metaphase.—In metaphase the granular nucleolar mass becomes flattened and the chromosomes are arranged in it in a plate (Text-fig. 45). As in the other forms the spindle is broadest at the equator and narrowest at the poles, beyond which there is an accumulation of cytoplasm. In a polar view of the metaphase plate obtained from a transverse section of the filament, eight chromosomes were counted (Text-fig. 46; Pl. II, Fig. 9). This number agrees with that obtained in late prophase stages. The hyaline area is still clearly seen round each chromosome.

Anaphase.—In anaphase the chromosomes divide first (Text-fig. 47). The hyaline areas round the chromosomes are no longer seen and the chromosomes appear thicker than during metaphase. Unlike the

condition seen in the other forms during anaphase, the chromosomes remain distinct from the stained nucleolar substance (Text-fig. 48). The spindle between the daughter plates as in the previous species becomes hollow and bulges out laterally.

Telophase.—During early telophase small dark bodies, short and rod-shaped or slightly longer, could be seen in the dark plates at the poles (Text-fig. 49). At this stage the nuclear membrane of the daughter nuclei are not yet organised and the nucleolar substance is still persisting. At a later stage the nuclear membrane is formed and inside this can be found a stellate darkly staining mass as in the other species (Text-fig. 50). Finally the two daughter nuclei are organised and a nucleolus could be seen in each (Text-fig. 51).

Discussion

Four species were examined in the present investigation, *Spirogyra columbiana*, *Spirogyra* sp., *S. Fuellibornei* and *S. paraguayensis*. In two of the species, *viz.*, *S. Fuellibornei* and *S. paraguayensis*, the outer nucleus remained unstained in iron-hæmotoxylin while in the remaining two species, *viz.*, *S. columbiana* and *S. sp.*, outer nucleus took up a light stain, and a definite reticulum with somewhat darkly staining granules at the corners of the meshes could be seen very clearly. Geitler investigated three species, *S. crassa*, *S.* sp. and *S. setiformis* in 1930 and one more species, *S. X*, in 1935. He used paracarmine as stain and mounted the material in Venetian turpentine. He found that in *S. setiformis* and *S. X*, the outer nucleus did not take up the stain, while in the remaining two species, *viz.*, *S. crassa* and *S.* sp., a number of darkly staining granules was found in the outer nucleus. These dark bodies were considered by him as chromocentres. It is not clear why in some of the species the outer nucleus remains unstained. Geitler (1930, p. 96) suggests that in these species the chromatin material in the outer nucleus is very probably masked by some substance and so remains unstained.

During early prophase, in all the four species examined by the author, the chromosomes become organised in the outer nucleus, while the nucleolus is quite intact and retains its sharp outline. The chromosomes are at first scattered in the outer nucleus, but at a slightly later stage are found gathered round-about the nucleolus, which is still quite intact (Text-figs. 3, 18, 29, 40). But very soon after this, the outline of the nucleolus begins to break up and the body of the nucleolus shows signs of disintegration. A little later, the nucleolus completely loses its sharp outline and its contents become more or less a mass of granular substance. The chromosomes, which had gathered round the nucleolus previously, are then seen entering into the granular nucleolar material. Finally all the chromosomes are seen completely imbedded inside the granular nucleolar mass (Text-fig. 7, 20, 31, 43). From the above it may be seen that a definite reticulum is present in the outer nucleus as in the higher plants, and that from this reticulum the chromosomes are gradually organised. That the chromosomes are formed from the outer nucleus and not from the nucleolus can be

clearly seen from the fact that the chromosomes are completely organised in the outer nucleus while the nucleolus is still quite intact and long before it begins to break up.

These observations of the author fully agree with those of Geitler (1930, 1935 *a*) made on the four species of *Spirogyra* investigated by him. He found that the chromosomes are organised in the outer nucleus while the nucleolus is still quite intact. The nucleolus then breaks down into a granular mass and the chromosomes enter into the nucleolar substance and are finally imbedded inside the granular nucleolar mass. He comes to the conclusion that the chromosomes take their rise from the outer nucleus and not from the nucleolus. He states that if one should miss the stage where the chromosomes are formed in the outer nucleus while the nucleolus is still intact and should see all the other stages, one could easily get the wrong impression that the chromosomes are formed first inside the nucleolus and then migrate outwards into the outer nucleus.

Stolley (1930, p. 929) stated that a mere morphological study of the nucleus was not enough and that a study of its chemical nature was necessary to decide the question of the origin of the chromosomes. A number of authors have studied the effect of Feulgen reaction on the nuclei of *Spirogyra*. Petter (1933), Shinke and Shigenaga (1933) and Yamaha (1935) found that the nucleus of *Spirogyra* did not show any positive reaction to Feulgen's stain. But Geitler (1935 *a*, *b*) who used the Feulgen's stain for a number of species found that in almost all of them the nucleolus in the resting nucleus remained quite unstained, while some granules (chromocentres) were stained in the outer nucleus. He found that these granules in the outer nucleus later on developed into chromosomes. From this he comes to the conclusion that the nucleolus does not contain any chromatic material and that all the chromatic material is lodged in the outer nucleus (reticulum) and that the chromosomes are derived from this outer nucleus (reticulum) as in the higher plants. Yamaha and Suematsu (1938) saw in another species of *Spirogyra*, chromocentres in the outer nucleus showing a positive reaction to Feulgen's test, while the nucleolus showed a completely negative reaction. Suematsu (1936) tried the stain on some Japanese species of *Spirogyra* and found that the nucleolus showed a negative reaction while the chromatic granules and chromosomes showed a positive reaction.

In the present investigation, the author used Feulgen's stain for one species, *viz*., *S. Fuellibornei*. He found that in the resting nucleus both the nucleolus and the outer nucleus remained unstained. But at the beginning of prophase some granules in the outer nucleus were stained, while the nucleolus remained unstained. During the later stages of prophase, the chromosomes showed a definite positive reaction to the stain, while the nucleolus, which was still quite intact, showed a completely negative reaction. The author's observations clearly showed that the chromosomes were derived from the reticulum and not from the nucleolus, and fully agree with those of Geitler (1930; 1935 *a*, *b*), Suematsu (1936) and Yamaha and Suematsu (1938).

Summary

A detailed account of mitosis in four species of *Spirogyra* is given in the paper.

The resting nucleus in all the four species contains a large nucleolus which takes a deep stain. The outer nucleus (reticulum) remains unstained in *S. Fuellibornei* and *S. paraguayensis*, but a lightly staining reticulum is seen in *S. columbiana* and *S.* sp. This reticulum is in no way different from that of the higher plants.

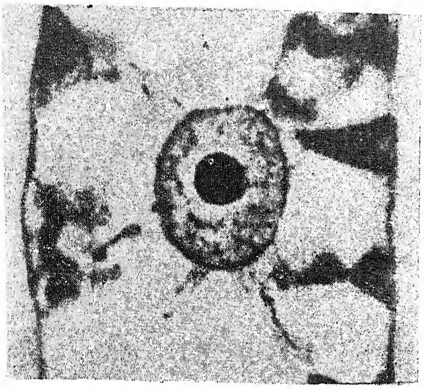
During prophase the chromosomes are formed in the outer nucleus while the nucleolus is still intact and has a sharp outline, showing clearly that they are formed from the outer nucleus (reticulum) and not from the nucleolus. About mid-prophase the nucleolus breaks down into a granular homogeneous substance, in which condition it persists throughout mitosis. During late prophase the chromosomes gradually enter the nucleolar substance and towards the end of prophase are seen completely embedded in it.

One of the four species, *viz.*, *Spirogyra Fuellibornei*, was stained in Feulgen's stain. The reactions of the nuclear structures during division shows (1) that the nucleolus does not contain any chromatin material, and (2) that the chromosomes are derived not from the nucleolus but from the outer nucleus (reticulum). It is concluded that the nucleus of *Spirogyra* is not fundamentally different from that of the other green algæ or of the higher plants.

In all the four species, during late prophase, a thin hyaline area is seen round each of the chromosomes which are imbedded in the nucleolar substance. This hyaline area persists during metaphase. But during anaphase, this hyaline area is no more seen. On the other hand, the chromosomes appear definitely thicker. Whether this hyaline area represents the matrix of the chromosomes which becomes chromophilic towards the end of metaphase could not be decided with certainty.

The spindle is cytoplasmic in origin and arises in the cytoplasm of the polar caps and extends later into the nuclear cavity.

The author wishes to express his great indebtedness to Prof. M. O. P. Iyengar, M.A., Ph.D. (Lond.), F.L.S., for his constant guidance and help during the course of this investigation. His thanks are also due to the authorities of the University of Madras for the award of a research scholarship during the tenure of which the present investigation was carried out.



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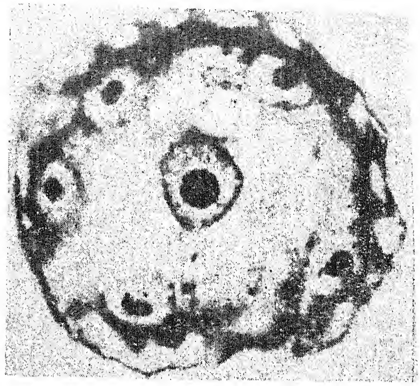

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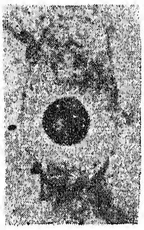

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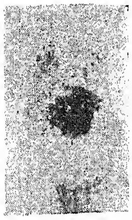

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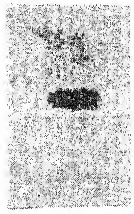

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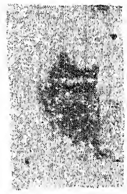

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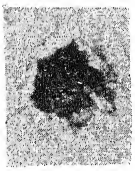

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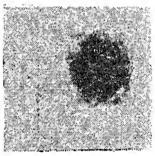

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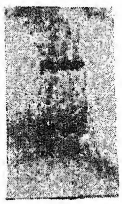

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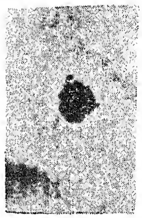

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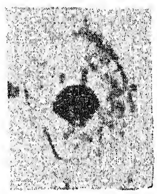

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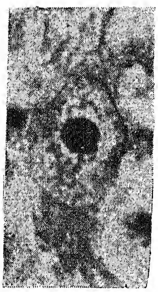

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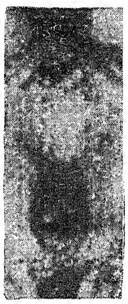

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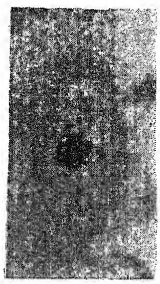

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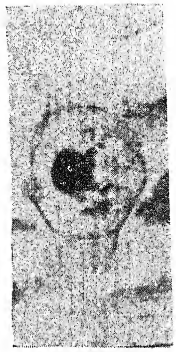

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S. DORAISWAMI—*NUCLEAR DIVISION IN* SPIROGYRA

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EXPLANATION OF THE PLATE

Figs. 1, 2, 8, 9, 11–13, 15 and 16 are from microtome sections, while the rest are from whole mount preparations.

Fig. 1. *Spirogyra columbiana*, longitudinal section of filament showing a resting nucleus with a well-defined reticulum.

Fig. 2. *Spirogyra columbiana*, transverse section of filament showing the nucleus and the cytoplasmie strands.

Fig. 3. *Spirogyra columbiana*, resting nucleus; note the vacuoles inside the nucleolus.

Fig. 4. *Spirogyra columbiana*, chromosomes arising in the outer nucleus.

Fig. 5. *Spirogyra columbiana*, late prophase showing chromosomes imbedded in the nucleolar substance; note the hyaline portion round each chromosome.

Fig. 6. *Spirogyra columbiana*, metaphase.

Fig. 7. *Spirogyra columbiana*, early anaphase.

Fig. 8. *Spirogyra columbiana*, polar view of metaphase.

Fig. 9. *Spirogyra paraguayensis*, polar view of metaphase.

Fig. 10. *Spirogyra columbiana*, late anaphase.

Fig. 11. *Spirogyra paraguayensis*, chromosomes organized in the outer nucleus while the nucleolus is still intact.

Fig. 12. *Spirogyra paraguayensis*, chromosomes organized in the outer nucleus while the nucleolus is still intact.

Fig. 13. *Spirogyra paraguayeusis*, early prophase showing long thread-like chromosomes in the outer nucleus.

Fig. 14. *Spirogyra columbiana*, telophase with the stellate dark mass in each daughter-nucleus.

Fig. 15. *Spirogyra paraguayensis*, nucleolus breaking up and the chromosomes entering the nucleolar substance.

Fig. 16. *Spirogyra paraguayensis*, chromosomes organized in the outer nucleus while the nucleolus is still intact.

Fig. 8 × 1,200; Fig. × 1,040; the rest × 900.

Professor M. A. Sampathkumaran

OBITUARY

Professor M. A. SAMPATHKUMARAN

(1887-1944)

MANDAYAM ANANTHANPILLAI SAMPATHKUMARAN was born on the 15th July 1887 at Melkote near Seringapatam in Mysore State. He came of a very highly cultured, orthodox Brahmin Sri Vaishnavite family. His father, Sri. M. A. Alwar Swamy, was a great and erudite Sanskrit scholar well versed in Indian Philosophy.

Sampathkumaran graduated from the Presidency College, Madras, in 1909 with Botany and Biology as his optionals. Immediately after graduation, he was appointed as Demonstrator in Botany at the Central College, Bangalore, on the 14th March 1910, when Botany was first introduced at the College. He was the only member of the Botany staff at the time and was solely responsible for starting and organizing the Botany Department of the College. In 1915 he went as a Mysore Government Scholar to America and studied under Prof. Coulter and Prof. Chamberlain at the University of Chicago and took the Doctorate of the Chicago University in the First Class in 1917. He was an Honorary Fellow of the University of Chicago from 1916 to 1917 and was an elected member of the Sigma XI Society from 1916. When he returned to India in 1919, he was made the Assistant Professor of Botany at the Central College —the professor's post was not yet created for the Botany Department of the College at the time. He became the Professor of Botany in 1923 and continued to occupy the Botany Chair till 1941. He acted as, the Principal of the College for a few months just before retirement in 1941.

Ever since the Botany Department of the Central College was started in 1910 and until his retirement in 1941, he was in sole charge of the Botany Department. He was continuously improving the Department and brought it to a very high state of perfection and made it one of the most up-to-date and leading botanical laboratories in India.

The late Dr. W. Dudgeon of Allahabad was a classmate of his at the Chicago University and returned to India about the same time as Sampathkumaran. Sampathkumaran and Dudgeon were pioneers of research work in Plant Cytology and Morphology in India. Sampathkumaran established an important school of research in Plant Cytology and Morphology at Bangalore, while Dudgeon established a similar school in North India at Allahabad.

Prof. Sampathkumaran's technique was of a very high order. Besides being an excellent technician in Cytology and Morphology of higher plants, he was a very good technician in other groups of plants also. Prof. Chamberlain in a letter which he wrote to Prof. Sampathkumaran in 1919 with reference to some fungi slides that the latter had prepared and sent to him says :—"I used the fungi slides in Special Fungi and they are just what we need. They take their place

with Yamanouchi's and Sharp's and Dudgeon's, so that successive student generations will now strive to emulate your technic in Fungi as they do Yamanouchi's in Algæ and Sharp's in root tips, and also Dudgeon's in fern anatomy. I hope both you and Dudgeon will use your technic in research. It is not so easy to keep at it when you are out of touch with a great research laboratory; but remember that Hofmeister and Schleiden *made* their own research atmosphere." Sampathkumaran certainly *made* his own research atmosphere and established a great school of plant morphologists at the Central College, Bangalore. Under his inspiring guidance his students published a very large number of valuable papers on Cytology and Plant Morphology. The publications from his Department form very important contributions to these subjects.

He presided over the Botany Section of the Indian Science Congress in 1927 and was the President of the Indian Botanical Society in 1942. He was throughout one of the staunchest supporters of the Indian Botanical Society. He was a member of the Board of Studies in Botany of the Mysore, the Madras and the Annamalai Universities for several years and was an examiner in Botany for a number of Universities in India for several years.

I was intimately associated with him for over forty years. He was a very affectionate, loyal and staunch friend, a most delightful companion and an excellent host. He had strong views on various subjects, but he was always tolerant of the views of others and never allowed his strong views to interfere with his friendship. He was of a very buoyant and cheerful temperament. He was a good mixer and a great cementing force and was responsible for bringing together the Indian Botanists in the earlier days. He was of a very generous and magnanimous disposition. He would do good to persons even though he knew that they had done him wrong or were talking ill of him.

He was a good footballer in his college days. He maintained very good health throughout his life and was always active and was never known to be seriously ill at any time. Unfortunately his end came all too suddenly and unexpectedly. He passed away suddenly on the 15th December 1944 after a very short illness. In his death the Indian Botanical world has lost a great and inspiring worker and his very large circle of friends an excellent friend and a most loveable companion. The gap that is left is not an easy one to fill.

M. O. P. IYENGAR.

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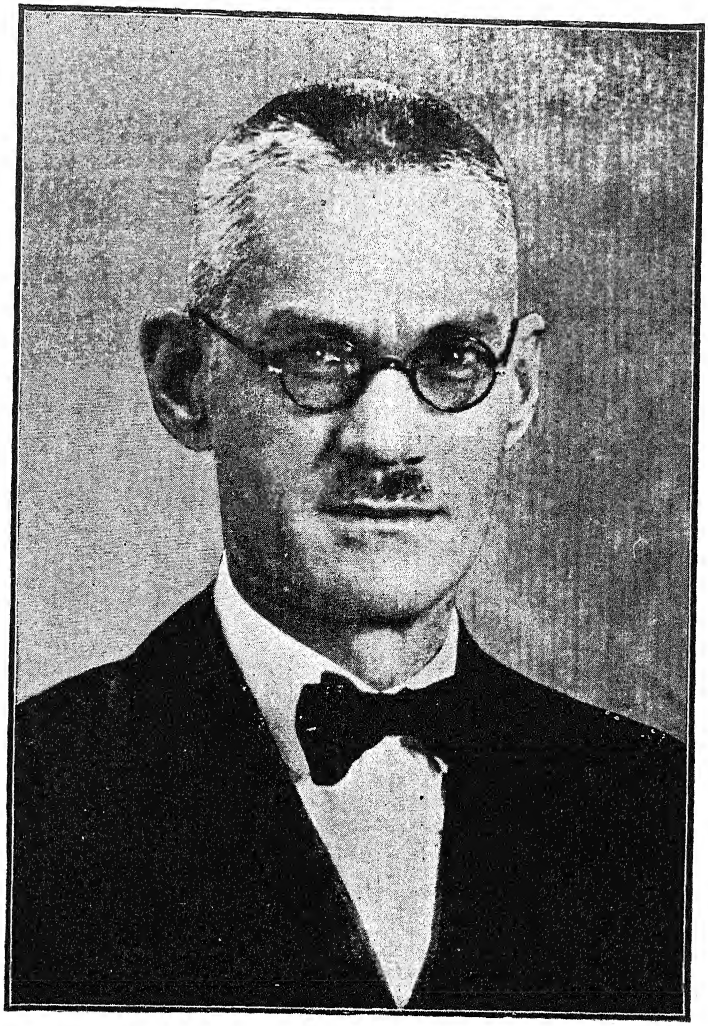

Winfield Scott Dudgeon
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AN ECOLOGICAL STUDY OF THE VEGETATION OF THE BENARES HINDU UNIVERSITY GROUNDS

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I. INTRODUCTION

THE campus of Benares Hindu University is nearly a rectangular area measuring about two miles from north to south and about one and a half miles from east to west. It is situated on a level ground near the bank of the Ganges about three miles to the south of the city. Twenty-eight years back the area was thickly populated with agricultural and industrial people spread in several villages. It had then a vegetation characteristic of the surrounding country. A part of it consisting of mango groves, mounds and ponds can still be found in the original condition while most of it was destroyed and modified with the construction work. Now this area is under buildings, gardens, playgrounds, roads and farming. Around these, a variety of habitats occupied mostly by a meadow vegetation, which consists of nearly 300 species of flowering plants and which shows strong seasonal aspects, has developed. The results of a study of these, largely done in 1942–43, are presented in this paper in a more or less topographic sequence of the habitats.

The low-lying lands, which hold standing water for the duration of the rainy season or for a longer period, are included in a separate study (Misra, 1946). Therein the tests on soil and the relevant climatological data for the area for the period of this investigation are also given. A detailed list of the species for each of the habitats with their frequency-abundance in the rainy, the cold and the hot seasons, their sociability and plant cover wherever necessary, have been published elsewhere (Misra, 1945). The climate has been described yet in another study (Misra, 1944).

II. The Vegetation

1. *General characters*

The optimum temperature and moisture conditions for plant growth are obtained during the rainy season when the vegetation attains a luxuriant monsoon aspect. It declines rapidly in the following cold season on account of lower temperature, drying soil and increased biotic activities. Nevertheless, a new flush of growth from the underground parts of the perennial herbs is obtained in the beginning of the hot season due to rise of temperature; but later, the increasing drought and biotic activities reduce the vegetation to a miserable hot season aspect.

Following the first fall of rains, the almost bare ground begins greening up in patches. The subsequent showers of the season, frequently falling in torrential downpour wash down much of soil and plant propagules from the sloping higher lands. Erosion of soil continues to be rapid here until an effective plant cover has grown to stabilise it, as later in the season. *Urochloa reptans* and species of *Panicum* grow up quickly from their seeds which were stored by ants in holes. *Evolvulus nummularius* and *Cynodon dactylon* having survived in stunted forms from the preceding hot season now spread over big areas. These are followed by the growth of a large number of seedlings and sprouting rhizomes as deeper layers of the soil get moistened. *Crotalaria medicaginea*, *Cassia tora*, *Bothriochloa pertusa*, *Dichanthium annulatum*, *Euphorbia* spp. and *Indigofera enneaphylla* are the chief among these. The sloping lands subject to much erosion get covered with *Aristida adscenscionis*. Dudgeon (1920) and Bor (1941) characterised it as a species of over-grazed areas, but here, there is always a high incidence of the species with alkaline soils exposed to heavy erosion; the latter condition following undoubtedly, at many places, continued grazing. Its abundant growth on old walls where rainwater has corroded the mortar joints is a further proof of the contention.

As the grounds look green, a large number of women and children flock there from the surrounding villages and scrape all the plants indiscriminately, right through the surface soil. Hungry cattle are also let loose for grazing. But there is a continued growth of the plants from below the eaten-up shoots, the deep buried parts and the late germinating seeds. This tussle between the growth of the vegetation and its biotic destruction continues until by the beginning of August the villagers, finding enough to feed their cattle nearer home, stop visiting the grounds so frequently.

By the middle of the rainy season, the grounds are covered with a thick mat of vegetation on account of the rapid growth coupled with the decline of the destructive biotic factors. The grasses grow high to their full stature. The waterlogged areas are covered with *Echinochloa colona*, *Alternanthera sessilis* and a number of sedges. Local edaphic conditions and plant processes such as vigour and competition are best reflected by the vegetation, everywhere indeed, during this season.

Most of the species flower and fruit on getting longer hours of sunshine through a clearer atmosphere of September. Now a number of new species join the vegetation. Of these *Ammania baccifera* in wet places, *Oplismenus burmanni* and *Setaria intermedia* in shaded dry places and species of *Eleusine*, *Eragrostis* and Compositæ in the open are very characteristic. These newer plants are capable of growing on a soil which is losing water rapidly, and can successfully compete with the older plants of the preceding wet season.

The well-grown rainy season vegetation disappears as abruptly in the month of October as it came during the rains. This is not so much on account of the drier conditions and the competition as for the destructive biotic factors, especially scraping which becomes rapid once again. Indeed very few plants are left to wilt down on the drying grounds. Of these, *Crotalaria medicaginea* is the first to dry up. The grasses turn yellow and the other species look dull brown. The dried remains, if not already removed for fuel, are attacked by white-ants, which now come up on the surface in very large numbers. They cast behind a light, porous, calcareous and nitrate-rich puffy earth which is poor in organic matter.

The minimum temperature in the cold season seldom falls so low as to stop plant growth and the frost injuries to the crop plants reported once in many years, are never in evidence in the natural meadow vegetation. But, the desiccating winds and the drying soil together with grazing and scraping tell heavily upon it. These conditions train most of the perennial meadow species into slow growing, prostrate and tufted depauperate forms which possess small, coriaceous or pubescent and dull looking leaves. The plants are chiefly : *Indigofera enneaphylla*, *Euphorbia* spp., *Bothriochloa pertusa*, *Dichanthium annulatum*, etc., forming open communities. *Eleusine ægyptica* and *Paspalidium flavidum* also grow to similar forms before they are dried up in December. The occasional winter rains may brighten them up but very temporarily.

The increasing temperature in March and April activates both vegetative and flowering growths. *Convolvulus pluricaulis*, *Evolvulus alsinoides*, *Boerhaavia diffusa* and the grasses spread out in the fields, and the low-lying lands look happier with abundant growth of *Mollugo hirta*, *Polygonum plebejum* and *Cynodon dactylon*. The deciduous trees bear new foliage, and blossom. The old leaves which have been shed off, are blown by the wind and deposited in depressions or against taller herbs. These are sweeped off for fuel by some of the village folk for frying grains, and so the organic matter from this source is lost to the soil.

Conditions for plant growth become extremely severe during the following hot days. The moist plant tissues have now to live between a dry soil and a desiccating atmosphere. The moisture content of the soil at the surface may decrease even upto 0·1% in the open, and the extremely low humidity coupled with strong wind at a higher temperature during the afternoons, would heavily tax the water content of any plant tissue. Indeed, only the most drought-enduring species

survive this ordeal. It is not uncommon to notice many plants and even branches of trees drying up in the month of May when the maximum temperature may go upto 115° F. It actually shot upto 119° F. in 1942, and as the records were taken in shade, the temperature of the exposed ground might well have been 40–50 degrees higher than these figures (*cf.* Dudgeon, 1920). Hence the surviving species must be heat enduring too. They invariably show variations in their form as a result of metabolic and growth adjustments. Prostrate and tufted habits with dwarfening effects reduce them to depauperate forms which bear coarsely veined leaves with a thicker deposit of cutin. Folding and rolling up of the grass leaves and, wilting in others, are found for the most of the day. *Heliotropium strigosum* and *Trichodesma indica* may grow slowly drawing nourishment out of the older tissues which are now cast behind to dry off. The grasses too send out young shoots from the rhizomes in a similar fashion. Older plants of *Boerhaavia diffusa, Convolvulus pluricaulis, Vernonia cinerea, Indigofera enneaphylla* and *Euphorbia granulata* seem to live on the supplies present in their enormous root systems.

Even the thin and sparse vegetation of the hot season is grazed and scraped, thus leaving big areas of white, dry and loosened earth on the grounds. A few occasional drizzles in the season are but poor solace and only at this time, a few small gray patches remind of some vegetation not worth the name.

2. *Mounds*

The mounds are old deposits of earth about ten to fifteen feet high. They have a flat top of varying expanse and steep to gently sloping sides. Three types of these are found on the grounds. Type 1 is found either singly and then surrounded by cultivated land, or in chains around tanks in the southern part of the University. This type is very old. Its surface is strewn with "kankar" (nodules of calcareous material) and pieces of earthenware and tiles showing its proximity to former villages. Type 2 consists of ten-year old deposits of soil dug out for the foundation of the temple which is under construction in the heart of the University. Its surface is rough and channelled by gully erosion. Type 3 is lying in the middle west of the area. It consists of deposits of cinder and moulding casts of clay used for making brass utensils. This was once a site of the village industry. It is now well wooded with 10–30-year old trees of *Ficus glomerata, F. religiosa, F. bengalensis, Bombax malabaricum, Melia azadirachta* and *Holoptelia integrifolia*. The meadow growth on all the mounds is scraped and grazed.

Type 1 mounds have a carbonate rich (3) and highly alkaline soil (pH = 8·3–8·5) which is light coloured, well compressed and poor in moisture content (0·5% to 0·8% in the dry seasons). *Aristida adscenscionis*, d ; *A. funiculata*, cd and *Desmostachya bipinnata*, ld are the commonest species on the mounds. The former two species dry up at the end of the cold season when *Blepharis molluginifolia* and other minor species become exposed and now spread over to

bigger areas. *Enicostema littorale* though sparsely distributed on the top of the mounds, is quite characteristic species of the situation, in the wet season. The maximum plant cover grows upto 75% of the ground at the end of the rainy season after which time, it may go down gradually falling upto 10% in the hot season.

Type 2 mounds consist of soft sandy loam with an average pH value of 8·0. It is pale and brown in colour and less saline (carbonate = 1) than the previous type. It is nitrifying (diphenylamine test= 1), opened by earth-worms during the rainy season and retains moisture upto 5·7% just after this time. These qualities of the soil account for a rich meadow vegetation which may cover upto 90% of the mounds at the end of the rainy season and is never less than 10% even during the dry seasons, despite grazing and scraping. But *Saccharum munja* and *S. spontaneum* (the latter appearing in the rainy season) are fast taking possession of most of the area on account of efficient rooting of their rhizomes. *Dichanthium annulatum* is the dominant species on the flat tops, and the steep slopes carry *Aristida adscenscionis*, with more of *Tridax procumbens* in the unstable gullies cut by erosion. *Indigofera enneaphylla* is very abundant on this type of soil and stands grazing and scraping well.

Type 3 mounds carry the poorest vegetation on account of a coarse, dark coloured and loose substratum of cinder and grits. It has a pH value of 7·80, carbonates are absent and its nitrifying capacity is very low (= 1). Nevertheless, many species like *Peristrophe bicalyculata*, *Rungia parviflora*, *Achyranthes aspera* and *Urochloa helopus* grow well on the mounds during the rainy season. These are followed by *Oplismenus burmanni* and later by *Nepeta ruderalis.* They all stand shade, and growing together, cover 50% of the ground in the month of October. This vegetation, in view of the poor nature of soil, is sustained primarily by the rains and high humidity ; the latter maintained for some time after the wet period by the overtopping trees. For, it rapidly dries up going down to less than 5% cover when dry winds blow in the following cold season. Only *Achyranthes aspera*, *Vernonia cinerea*, *Justicia diffusa*, *Rungia parviflora* and a few minor species remain till the end of the cold season.

The vegetation of the 3rd type of mounds may be compared with that found in shaded parts on the other two types. The old, alkaline and compressed substratum of the first type bears *Bothriochloa pertusa* and species of *Sporobolus*, in abundance, under shade. Since these species grow characteristically in the open on flat lands having a soil similar to type I, their incidence here, under the shade, may be accounted for by a lack of competition by other species. Type 2 mounds under similar situations grow a number of characteristic shade loving species such as *Setaria* spp., *Desmodium* spp. and *Sida veronicæfolia*, and a few others like *Eragrostis tenella*, *Digitaria* spp., *Sporobolus* spp., *Manisuris granularis*, *Alysicarpus monilifer* and *Tridax procumbens* which do well in shade, only when growing on rich soils. *Peristrophe bicalyculata* seems to be more characteristic on a loose soil open to rapid erosion, but has a decided preference for shade, when growing

on more stable and richer soil. *Rungia parviflora* on mound 3, is a shade-species on sandy soil ; and *Nepeta ruderalis*, by its occurrence on ash and also on organic deposits near villages, indicates a liking for potassium. *Oplismenus burmanni*, on the other hand, is a definite shade loving species growing on a sloping land. This tender grass has a rapid growth, but is easily ousted by other species on account of its weakness for moisture.

3. *Bunds*

Bunds of earth, carrying on their top pucka channels to lead water for irrigation, run in different parts of the University grounds. These were constructed about 5 years back by working up the surrounding soil to a height of 4–6 feet with sloping sides which are now covered by plants. Seepage water from the channels keeps the substratum locally moist, and here a good lawn has grown which is frequently grazed and scraped. The soil consists of a sandy brown loam which shows slight seasonal variations in its characters. It has an average pH value of 8·40, a moderate carbonate content (1) and a good nitrifying capacity (3). The water content varies from 6·7% in October to 1·5% in April.

Richness of the soil with regard to salts and moisture is chiefly responsible for a green appearance of the bunds throughout the year. The vegetation consists of a large number of species showing strong seasonal aspects. But *Croton sparsiflorus* has, by now, become the dominant species. Joshi (1934) saw it first in Benares on the bank of the Ganges, in 1931, and then reported its arrival in the United Provinces from the eastern part of the country. It has now spread throughout the University area and the town. It is chiefly associated with the construction of buildings, roads and canals, as the seeds are carried to these places with sand taken from the bank of the river ; and this would explain its absence from the surrounding villages where such construction does not usually take place. *Cynodon dactylon* finds the sloping moist bund a very favourable habitat. On flat dry grounds or waterlogged soils it is unable to stand competition by other species. The same facts hold good for *Oplismenus burmanni* which covers shaded parts of the bund at the end of the rainy season.

4. *Waste grounds and deposits of building materials*

Small pieces of rough land, both in open and shaded situations, are often seen bearing taller herbs. Where the ground is smooth and moist, it is covered by a lawn also. These are subject to grazing and scraping as usual and so either the coarser taller plants are left out, or those which can regenerate quickly from their underground parts.

The actual number of species found in such regions is quite large and here, only those few are listed which give a definite aspect to the vegetation. Most of these are very gregarious in habit. *Cassia tora*, *Crotalaria medicaginea* and *Triumfetta neglecta* are especially prominent in the rainy season. *Anesomeles ovata*, *Hyptis suaveolens* and *Peristrophe bicalyculata* grow in shade, becoming attractively tall at the

end of the season. As these species dry up in the cold season the remaining lower ones like *Achyranthes aspera*, *Croton sparsiflorus*, *Amarantus spinosus*, *Ocimum bacilicum*, *Tephrosia purpurea*, *Scoparia dulcis*, *Sida rhombifolia* and *Vernonia cinerea* become more prominent. *Argemone mexicana* appears late in the season. The lower meadow species are chiefly, *Bothriochloa pertusa*, *Dichanthium annulatum*, *Cynodon dactylon*, *Aristida adscenscionis*, *Paspalidium flavidum*, *Eragrostis* spp., *Sporobolus* spp., *Echinochloa colona*, *Digitaria* spp., *Eleusine* spp., *Cyperus* spp., *Kyllinga* spp., *Fimbristylis* spp., *Corchorus acutangularis*, *Echinops echinatus*, *Volutarella divaricata*, *Justicia diffusa*, *Tridax procumbens*, *Boerhaavia diffusa*, *Convolvulus pluricaulis*, *Euphorbia* spp. and *Indigofera enneaphylla*. *Triumfetta neglecta*, *Trianthema monogyna* and later, in the cold season, *Nepeta*, *ruderalis*, grow abundantly on heaps of organic matter.

A considerable part of the grounds in the south end of the University, is occupied by brick fields. These consist of a number of kilns surrounded by uneven land, as the latter was irregularly dug out for laying bricks. The older fields were abandoned about ten years back, and in the mean time a characteristic vegetation has come up.

The brick kilns consist of circular and oval trenches. These are about 6–8 feet deep and about 12 feet wide, and each surrounds a piece of land standing like an island. The outer margin of the trench is enforced with a 2–3 feet high sloping bund of earth in order to keep out drainage water, which might but for it collect into the ditch from the surrounding lands during the rains.

The soil of the kilns is much modified on account of baking operations which obtained here before. It is carbonate-free unlike the surrounding area, and possesses a moderate capacity of nitrification (1). The pH values fluctuate a little during the different seasons : here only the average values are recorded. On the bund, it is a red brown sand with pH = 7·15, and the island has a brown sandy loam with pH = 6·92. The bed of the trench has developed now into a soil of the latter type with pH = 6·22, though formerly it was baked into a red earth as found in the working kilns of to-day. Some coal powder may be found mixed with the soil throughout the area.

The three regions, though floristically distinct, bear equally rich growth during the rainy season on account of the soil being saturated with more than 20% water. The characteristic species of the bund are : *Aristida adscenscionis*, *Urochloa reptans*, *Tragus racemosus*, *Sporobolus* spp. and *Digitaria sanguinalis*, as indicators of soil erosion, and *Indigofera enneaphylla*, *Heliotropium strigosum*, *Boerhaavia diffusa*, *Convolvulus pluricaulis*, *Zornia diphylla*, *Dichanthium annulatum*, *Eragrostis* spp. and *Eleusine ægyptica*, as indicators of grazing and scraping. The islands being comparatively inaccessible, are less affected by the biotic factors, and hence, there grow a number of tree seedlings such as those of *Tamarindus indicus*, *Streblus asper*, *Azadirachta indica*, *Mitragyna parviflora*, *Zizyphus jujuba* and *Acacia arabica*, besides

Saccharum munja and a meadow. The bed of the trenches remains more humid and shaded along the walls. Here a larger number of ephemerals are found. The chief ones are: *Crotalaria medicaginea*, *Polygala chinensis*, *Aneilema nudiflorum*, *Oldenlandia pectinata*, *O. corymbosa*, *Vandellia crustacea*, *Bonnaya brachiata*, *Cyperus rotundus*, *C. compressus*, *Echinochloa colona*, *Eragrostis tenella*, *Fimbristylis diphylla*, *Panicum psilopodium*, *P. trypheron*, *Paspalum scorbiculatum*, *Juncellus pygmæus*, *Setria* spp., etc. *Saccharum munja*, *Saccharum spontaneum*, *Euphorbia* spp., *Rungia parviflora*, *Cynodon dactylon* and *Evolvulus nummularius* also grow here abundantly.

During the dry seasons the soil loses most of its moisture. The sandy bund in December had only 0·93% of water when the island had 1·08% and the bed of the trench as much as 3·40%. But, in spite of the differences in moisture content at this time, the vegetational cover is almost equal in the three cases, being 30 to 40%, on account of a continued growth of drought-enduring species in the drier regions where the perennials were more abundant, even during the rainy season. Species of *Blumea*, *Salvia plebeja*, *Gnaphalium indicum*, *Nicotiana plumbaginifolia*, *Argemone mexicana*, etc., come up more abundantly in the moist trenches, replacing the rainy season ephemerals.

The old brick walls around the trenches are broken at several places where now the earth is exposed and subjected to erosion during the rains. Since they are free from biotic disturbances these bear local patches of dense vegetation, especially in the crevices. *Lindenbergia polyantha*, *Chloris virgata* and species of *Ficus* are very characteristic of the brick paved walls, while *Digitaria sanguinalis*, *Aristida adscenscionis*, *Urochloa reptans*, and *Boerhaavia diffusa* are constantly found on the cutcha parts. The last named species comes out of root stocks penetrating to the walls from the surrounding higher bund.

The pitted area around the kilns forms a number of small pools during the rainy season. These are included in a separate study (Misra, 1946). Here the low and gently sloping meadowlands, as separated by small bits of the original land, will be examined. The species common to the whole of the area are: *Saccharum munja*, *S. spontaneum*, *Crotalaria medicaginea*, *Zornia diphylla*, *Digitaria* spp. and *Cynodon dactylon*. The higher lands are very much eroded showing out rounded grits, and bear an open vegetation consisting of the above-named species and *Aristida adscenscionis*, *Alysicarpus monilifer*, *Bothriochloa pertusa*, *Convolvulus pluricaulis*, *Polygala chinensis*, *Echinops èchinatus* and locally, *Anesomeles ovata*. The lower sloping meadowlands lie on a pale brown loam with an average pH of 7·20, and besides the common species, possess such others as: *Scoparia dulcis*, *Fimbristylis diphylla*, *Paspalum scorbiculatum*, *Panicum psilopodium*, *Euphorbia hirta*, *Aneilema nudiflorum*, *Cyperus rotundus*, *Evolvulus nummularius*, *Desmodium triflorum* and *D. parvifolium*.

Building materials such as bricks, grit and sand have quite often remained deposited for a sufficiently long time to be overgrown by a vegetation. A comparative study of such habitats has been chiefly made on the temple grounds,

The plants growing on the brick heaps, are rooted either to the ground below or to the soil collected in between the bricks. The newer deposits show a growth of *Tridax procumbens*, *Bothriochloa pertusa* and *Justicia quinqueangularis*. The old deposits get many more species, besides these, such as *Achyranthes aspera*, *Dichanthium annulatum*, *Digitaria sanguinalis*, *Echinops echinatus*, *Bidens pilosa* and *Cynodon dactylon*. They all send out a number of flexible shoots growing out of the crevices.

The plants, growing on the deposits of grit and sand, are truly characteristic of the loose substratum. Their root systems are extremely deep, and the shoots are too rigid and coarse. *Tridax procumbens*, *Indigofera enneaphylla*, *Cynodon dactylon*, *Argemone mexicana*, *Solanum xanthocarpum* and *Calotropis procera* are found on the grits with varying frequency. On the sand, which has a pH value of 8·20, many more species besides those of the grit, grow. Of these *Saccharum munja*, *Euphorbia dracunculoides*, *Xanthium strumarium*, *Chrozophora rottleri*, *Cyperus rotundus* and *Alysicarpus monilifer* are quite characteristic. It is interesting to note that an old deposit of clay, on the grounds, does not show any of the above mentioned species. The clay has a pH value of 7·16 and is well nitrifying (2). Here the characteristic species are *Convolvulus pluricaulis*, *Merremia emarginata*, *Paspalidium flavidum* and *Tragus racemosus*. It may however, be noted that a few miles away from this area *Xanthium strumarium* is very abundant on clay, but only when it is in shallow regions becoming waterlogged during the rains.

5. *Along buildings and hedges*

The surroundings of the buildings including the flower beds and the hedges get infested with a large number of weeds, as they receive lapsing attention of the Mali, especially during the long vacations of the University. These include invasions from the neighbouring vegetation, as also many exclusive and characteristic species. The special circumstances of the habitat are : a high humidity, as the wind is checked, and a soil moistened by water from the flower beds and the buildings. The northern side of the high buildings provides a shaded aspect in contrast to the sunny aspect of the other sides.

There are narrow lanes lined by low cut hedges of *Justicia gendarussa* leading to the steps of the verandahs. These are only moderately frequented, as the main approaches to the buildings are from the other sides. Nevertheless, the soil is sufficiently compressed on account of treading. The following species are common to the sunny region : *Tridax procumbens*, *Bothriochloa pertusa*, *Evolvulus nummularius* and *E. alsinoides* with *Eleusine indica*, in the rainy season. The species common to the shaded lanes are : *Amarantus viridis*, *Nicotiana plumbaginifolia*, *Biophytum sensitivum*, *Gnaphalium* spp., *Oxalis corniculata*, *Potentilla supina*, *Rungia parviflora*, *Solanum nigrum*, *Desmodium triflorum* and species of *Setaria* in the rainy season, and *Ageratum conyzoides*, *Celsia coromandelina* and *Euphorbia geniculata* in the cold season. The species which are common to both the sunny and the

shaded parts are : *Euphorbia* spp., *Cyperus rotundus* and *Eragrostis* spp.

The characteristic species of the gravel walks are : *Amarantus spinosus, Sida rhombifolia, Tridax procumbens, Digitaria longiflora, Euphorbia* spp. and *Launea nudicaulis* with *Chloris virgata* and *Eleusine indica* during the wet season.

Water, running down the drains of the laboratories, provide an inundated and stagnant habitat around these buildings. Here, in the open, the commonest species are : *Ficus* spp., *Striga euphrasiodes, Aneilema nudiflorum, Eclipta alba, Cyperus rotundus, Echinochloa colona, Fimbristylis miliacea, Panicum psilopodium, Cynodon dactylon, Portulaca oleracea* and *Trianthema monogyna* ; and in the shade these are : *Amarantus viridis, Celsia coromandelina, Ficus* spp., *Aneilema nudiflorum, Commelina bengalensis, Eclipta alba, Oxalis corniculata, Potentilla supina, Rungia parviflora, Echinochloa colona, Cynodon dactylon* and *Solanum nigrum*.

The beds of flower and those of the hedges provide nutritive and moist substratum for the growth of a large number of weeds and tree seedlings under partial shade. The commonest species are : *Conyza ambigua, Euphorbia hirta, Scoparia dulcis, Solanum nigrum, Tridax procumbens, Cyperus rotundus, Eragrostis* spp., *Sida acuta, Bothriochloa pertusa, Eriochloa ramosa, Panicum psilopodium, Setaria* spp., *Cyperus rotundus, Acalypha* spp., *Euphorbia geniculata, Biophytum sensitivum, Oldenlandia corymbosa, Phyllanthus niruri, Physalis minima, Digitaria* spp. and *Blumea* spp.

The hedges provide a support to the following climbers which grow frequently during the rainy season : *Ipomea pestigridis, I. scindica, Clitoria ternatea, Convolvulus arvensis* and *Rhynchosia minima*.

6. *Roadside*

The University roads run for a total length of over twenty miles. These are generally 10–15 feet wide, and, except for short distances in the extreme south, they are pucka being constructed of pieces of flag stone. A few of these are built entirely of 'kankar' but in every case they are occasionally dressed with this material when in need of repairs. A level cutcha footpath, 6–9 feet in width, runs on either side of the road. This is followed by a 15–20 feet wide gradually sloping meadowland which ends into a 4–6 feet wide cutcha drain ; the latter is meant for carrying away the rainwater. There is usually a row of about twenty years' old avenue trees on either side of the drain. A section of the roadside is shown in Fig. 1.

Heavy showers of rain wash the road, and the water rushes down the footpath and the meadowland into the drain. In doing so it carries with it the leachings of the 'kankar' as it is powdered by vehicular traffic on the road, thus enriching the soil of the lower levels with calcium and carbonates. On the loss of the calcareous matrix the stone pieces of the road are exposed,

When the roads are dry during the cold season, the traffic raises up dense clouds of dust which settle down on the neighbouring vegetation. Its deposit on the plants may be sufficiently thick to choke many of them to death, at the busier roads. *Cassia tora* seems to suffer especially on this account, as locally on the less frequented roadside it may still be found flowering and fruiting, and further, there is a certain rejuvenation of the dust-covered plants when washed clean by occasional rains. *Euphorbia hirta*, on the other hand, stands well a dust cover. However, in open and drier situations it becomes red coloured due to synthesis of anthocyanins in the tissues which suffer from a deficiency of nitrogen on account of its low absorption from a cool and dry soil.

The worn-out roads are repaired at this time. The silted drains are dug deeper and the earth so removed is deposited on the eroded footpath and meadowland. This causes local destruction of the vegetation, but it regenerates soon in the original form.

The 'loo' in the following hot season sweeps the dust off the road and causes some erosion of the soil from the meadowland too. This exposes the underground parts of the perennials, which now give out dwarfened shoots while the more extensive older branches are drying, breaking and blown up under their bases, thus leaving a bare swept ground between the smaller individual plants.

A line transect study of a typical roadside is given in Fig. 1 and Table I. Here the line is divided into ten parts, and the number of individuals belonging to each species as distributed on the different parts are recorded for August and December. It will be seen from such a study that the footpath, the meadowland and the drain have each a different set up of the vegetation. These are hence described separately.

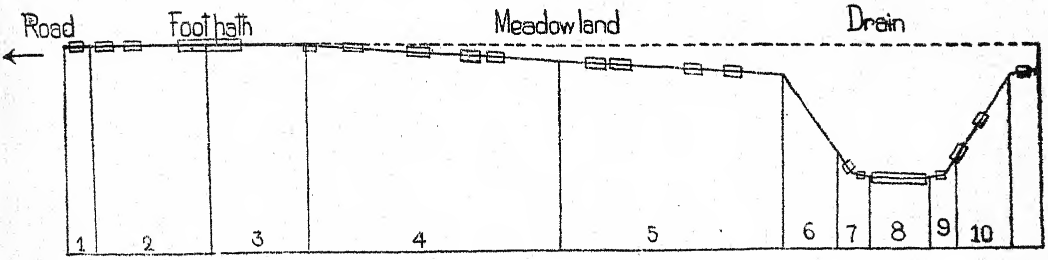

Fig. 1

Line transect across a typical roadside

Broken line=level of the road.

1–10 are the parts as given in the text.

Rectangles = areas without any plant on 28-8-'43.

TABLE I

A line transect study of a typical roadside

(The two horizontal rows of figures, for the cover and each of the species, correspond to records as obtained in August and December 1943)

Parts of the line	1	2	3	4	5	6	7	8	9	10
Cover (on 1–5 scale)	>1	2	4	4	4	5	4	0	4	5
	>1	>1	>1	2	3	4	4	0	4	3
Paspalidium flavidum ..	1	18	20	3	2	2	..	..	2	3
	Dry	..	..	..	..	..	..	..	..	..
Urochloa reptans ..	..	5	15	57	51	2	..	..	1	10
	Dry	..	..	..	..	..	..	..	..	..
Indigofera enneaphylla ..	1	..	1	9	7	7	..	..	..	..
	..	..	..	12	17	5	..	..	..	..
Cyperus compressus ..	..	1	2	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..
Tribulus terrestris ..	..	..	1	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..
Cassia pumila ..	..	..	1	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..
Panicum psilopodium ..	..	..	..	3	1	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..
Cynodon dactylon ..	..	..	..	1	..	1	3	..	2	2
	..	..	..	..	1	6	8	..	2	12
Convolvulus pluricaulis ..	..	..	..	..	1	..	..	..	..	..
	..	..	2	3	4	2	..	..	..	3
Evolvulus alsinoides ..	..	..	..	..	..	..	..	..	..	..
	..	..	..	1	2	..	..	..	..	..
Tragus racemosus ..	..	..	..	..	1	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..
Alyscicarpus monilifer ..	..	..	..	..	1	2	1	..	1	..
	..	..	..	..	..	2	..	..	2	2
Dichanthium annulatum	..	..	..	..	..	6	..	..	..	..
	..	..	..	4	12	5	..	..	..	5
Scoparia dulcis ..	..	..	..	..	..	1	..	..	..	..
	..	..	..	..	..	..	..	..	..	..
Evolvulus nummularius ..	..	..	..	..	..	1	..	..	2	3
	..	..	..	..	..	..	..	..	3	7
Cyperus rotundus ..	..	..	..	..	..	1	1	..	..	..
	..	..	..	..	..	..	2	..	..	..
Desmodium triflorum ..	..	..	..	..	..	..	1	..	1	..
	..	..	..	..	..	..	..	..	2	2
Alternanthera sessilis ..	..	..	..	..	..	..	1	..	..	..
	..	..	..	..	..	..	..	..	..	..
Echinochloa colona ..	..	..	..	..	..	..	5	..	3	..
	..	..	..	..	..	..	..	..	..	..
Vernonia cinerea ..	..	..	..	..	..	..	..	..	..	1
	..	..	..	..	..	3	..	..	..	..
Eragrostis tenella ..	..	..	..	..	..	..	..	..	..	1
	..	..	..	..	1	..	..	..	..	..
Polygala chinensis ..	..	..	..	..	..	..	..	..	..	1
	..	..	..	..	..	..	..	..	..	..
Eleusine aegyptica ..	10	12	8	2	1	..	..	..	..	..
	..	..	..	6	6	..	..	..	..	..
Euphorbia hirta ..	..	..	..	..	1	..	..	..	..	..
	..	..	..	3	1	..	..	..	..	..
Boerhaavia diffusa ..	..	..	..	1	..	..	..	..	..	..
	..	..	..	2	..	..	..	..	..	..
Indigofera linifolia ..	..	..	..	..	..	1	..	..	..	..

Footpath.—Pedestrians trample over the vegetation and kill it on the central track, while its growth is modified to varying extent on the outer side (*i.e.*, towards the meadowland) depending on the intensity of the operation. The inner side (*i.e.*, towards the road) of the footpath consists of the exposed stone pieces holding gravel and sand between them. It carries a sparse growth which is occasionally bruised and compressed by the road traffic. While the outer strip of the vegetation is scraped, the inner one is spared as the stony substratum is so unworkable.

The sand of the inner strip has a pH value of 7·84, carbonate = 2, nitrate = 1 and water content = 0·27%, in the month of October. The characteristic species of this region are: *Digitaria longiflora*, *Cynodon dactylon*, *Indigofera enneaphylla* and *Euphorbia* spp. with depauperate forms of *Paspalidium flavidum* and *Eleusine ægyptica* growing abundantly during the rainy season. The vegetational cover is very meagre and almost disappearing during the dry seasons.

The outer strip consists of a pale sandy loam enriched with the calcareous matter washed out of the road. Its pH value is 8·56, carbonate = 3, nitrate = 1 and water content = 0·89%, in October. It shows great seasonal difference in the vegetation. *Paspalidium flavidum*, in a depauperate form, is the dominant species of the vegetation during the rainy season. *Eleusine ægyptica*, *E. indica*, *Sporobolus* spp. and *Urochloa reptans* are characteristic associates, and *Tragus racemosus* and *Tribulus terrestris* are almost exclusive to this region. Most of these plants die off during the cold season, when species of *Euphorbia*, *Indigofera enneaphylla*, *Convolvulus pluricaulis* and *Evolvulus alsinoides* give to it an entirely changed aspect. This strip might be eroded down to the level of the meadowland by the end of the rainy season, and now, on account of the similarity in vegetation, they merge completely into each other.

Meadowland.—The sloping meadowland consists of a loam mixed with fine sand, and is full of earth-worms during the rainy season. Its pH value is 8·36, carbonates = 2, nitrates = 2 and water content = 1·03%, in the open, and 11·54% in the shade of the trees, at the same time in October. It bears a rich meadow vegetation which is denuded frequently by scraping and grazing.

The characteristic species of the open are: *Alysicarpus monilifer*, *Bothriochloa pertusa*, *Croton sparsiflorus*, *Desmodium triflorum*, *Eupharbia hirta*, *Indigofera enneaphylla*, *Orthosiphon pallidus* and *O. rubicundus*, *Urochloa reptans*, *Paspalidium flavidum* and *Evolvulus nummularius* appear abundantly during the rainy season, and *Convolvulus pluricaulis*, *Evolvulus alsinoides*, *Euphorbia prostrata*, *E. thymifolia* and *E. granulata* become more abundant during the dry seasons. The average plant coverings in the rainy, the cold and the hot seasons are 90%, 50% and 25% respectively.

The species of the shaded parts are: *Echinochloa colona* and *Commelina bengalensis* during the rainy season, *Eragrostis tenella*, *Oplismenus burmanni*, *Rungia parviflora* and *Setaria intermedia* in the

latter part of this season and the cold season, and *Cynodon dactylon* and *Sporobolus* sp. continuing to grow throughout the year. The average plant coverings for the three seasons, beginning from the rainy season, are 100%, 80% and 35%.

Drains.—The system of drains running along the roads, carry away rainwater from the whole of the grounds and as its bulk increases, they are dug wider and deeper towards the north. They remain dry, except during the rains when inundated by flowing drainage water. During the rainy season some water may be held up, in pits formed at the bottom, or bound by landslides, thus forming small pools. These are included in a study of the lowlying lands (Misra, 1946).

The drain wall is sloping unless cut vertical by rapid erosion as in the north. Where the latter condition obtains during the rainy season, very few species such as *Evolvulus nummularius* and *Cynodon dactylon* are found taking root on the surface as they hang down along the edge. Where erosion is moderate these are joined by *Urochloa reptans*, *Echinochloa colona* and *Cyperus rotundus*. In the upper parts where erosion is only periodical, following heavy rains, the wall is fully covered with these, and *Aristida adscenscionis*, *Alysicarpus monilifer*, *Bothriochloa pertusa*, *Desmodium triflorum* and *Indigofera enneaphylla* give it a meadow aspect. In the following dry seasons the drain wall bears the same vegetation as the flanking meadowland.

The bottom of the drain remains saturated with water for the most of the rainy season. The soil is finer here with pH = 7·70, carbonates = 1, nitrates = 2 and water content = 16·30% in October. It gets sparsely covered with *Urochloa reptans* in the beginning of the rainy season but later, the plants get choked with mud and water. The vegetation following it, consists of a mixture of marsh and meadow species ; the latter continue to live for the dry seasons. The characteristic marsh species are : *Alternanthera sessilis*, *Ammania baccifera*, *A. peploides*, *Cyperus rotundus*, *Commelina nudiflorum*, *Cyanotis axillaris*, *Cæsulia axillaris*, *Echinochloa colona* and *Fimbristylis miliacea*, and the commonest meadow species are : *Cynodon dactylon*, *Fimbristylis diphylla*, *Evolvulus nummularius*, *Aneilema nudiflorum*, *Bonnaya brachiata*, *Vandellia crustacea* and *Merremia emarginata*. During the dry seasons, the deeper parts which held water for a longer time in the rainy season get, besides the meadow species, *Sphæranthus indicus*, *Gnaphalium* spp. and *Mollugo hirta*.

The cutcha roads as found in the south of the grounds bear many of the wasteland species but the following are quite characteristic : *Digitaria royleana*, *Eleusine ægyptica*, *E. indica* and *Paspalidium flavidum* during the rainy season, and *Echinops echinatus*, *Volutarella divaricata* and *Solanum xanthocarpum* during the dry seasons, and *Cynodon dactylon* throughout the year.

7. *Playgrounds*

The plants growing on the extensive and flat playgrounds of the University are subject to immense treading by a large number of

players during the working terms and periodic scraping and grazing during the vacations. The hockey, the tennis and the volleyball courts are especially prepared for the games. In doing so, the vegetation is completely removed save the underground root stocks which might be deeply buried. These gradually send up shoots, and as soon as the pressure of the games declines, the fields tend to go wild with the germination of viable seeds and colonists from the neighbouring lands joining these.

The soil of the football fileds is an alkaline (pH = 7·5–8·0) light coloured loam giving a positive test for carbonates. It is kneaded and compressed by the activity of the players, and the compactness and efficient drainage may account for its low moisture content which was found to be 1·5% in September and only 0·1% in April.

In the beginning of the rainy season, *Urochloa reptans*, *Evolvulus nummularius*, *Cyperus rotundus*, *Indigofera enneaphylla*, *Heliotropium strigosum*, *Orthosiphon rubicundus*, *Cynodon dactylon*, *Desmodium parviflorum*, *Zornia diphylla* and *Eleusine ægyptica* grow into a good lawn under the pressure of players' feet. The less frequented parts are covered with a turf of *Sporobolus* spp., *Dichanthium annulatum* and *Eragrostis* spp., growing in bunches along with the ephemerals. In the following dry seasons *Convolvulus pluricaulis*, *Evolvulus alsinoides* and *Boerhaavia diffusa* grow profusely with their rose, white, blue and pink coloured flowers presenting a beautiful aspect in the early hot season.

The moister places are generally covered with *Aristida adscenscionis*, *Panicum trypheron*, *Eragrostis elongata*, *Cyperus* spp., etc., during the rainy season, but later become barren and remain so for the rest of the year. This is due to alkali salts from the leachings of the surrounding land being deposited there on drying. In presence of humus and algal growth, the earth breaks up into dark gray flakes which disintegrate later leaving white patches below. Species of *Luphorbia* and *Indigofera enneaphylla* may be found making a poor growth on this saline soil during the dry seasons.

The cutcha tennis courts are prepared by levelling, rolling and finally coating the ground with cowdung. When the courts are not in use during the hot season, *Trichodesma indica*, a ; *Boerhaavia diffusa*, o ; *Convolvulus pluricaulis*, o ; *Evolvulus alsinoides*, f ; and *Euphorbia hirta*, r come up from their buried parts (Fig. 2). In doing so they open the soil, as it is more efficiently done by black ants which pile up loosened earth around their holes. Now, with the occasional showers of rain, it becomes favourable for the germination of seeds of many other weeds and for the growth of more deeply buried rhizomes as those of *Desmostachya bipinnata*. By the end of the rainy season the courts get fairly covered with a vegetation of the following composition : *Convolvulus pluricaulis*, o ; *Boerhaavia diffusa*, o ; *Desmostachya bipinnata*, r–o ; *Eleusine ægyptica*, f ; *Euphorbia hirta*, o ; *Eragrostis elongata*, f ; *Eragrostis tenella*, o ; *E. viscosa*, o ; *Scoparia dulcis*, r ; *Tribulus terrestris*, o–f ; *Trichodesma indica*, o ; *Urochloa reptans*, f ; and *Vernonia cinerea*, r.

The volleyball grounds bear chiefly, *Scoparia dulcis*, f ; *Pulicaria crispa*, o ; *Eragrostis* spp. and a few of the tennis court elements, in the hot season. These are scraped off in July for the game. The hockey fields tend to grow more like the football fields whenever these are not much in use.

8. *Grasslands*

Several acres of grassland surround the College buildings, as the land is enclosed for the purpose of developing garden and lawn. The soil consists of a light brown loam rich in carbonates (= 3) with pH = 8·35. Nitrate content is moderate and the water content in April is as low as 0·64%.

Bothriochloa pertusa and *Dichanthium annulatum* growing upto a height of 4 feet, during the rainy season, almost fill up the areas. The more neglected parts are dotted with young trees of *Acacia arabica*. The grasses are mowed for hay in September or October ; they grow, thereafter, prostrate forming agreeable lawns. The following subordinate species are exposed on the removal of the top growth when they do better : *Rhynchosia minima*, *Indigofera enneaphylla*, *I. linifolia*, *Boerhaavia diffusa*, *Euphorbia* spp., *Cynodon dactylon*, *Evolvulus alsinoides* and *Convolvulus pluricaulis*. Another but poorer crop of hay is obtained at the end of the cold season if the land has been kept free of grazing and scraping. The study shows how a little planning, by affording periodical protection to the lands against the biotic factors, would improve the meadowlands. However, continued protection leads to a deterioration of the grasses as they are strangled by the twining of *Rhynchosia minima* which grows rapidly even during the dry seasons. It has been so observed in one of the experimental plots.

Local depressions in the grasslands bear a vegetation similar to those of the football fields, except that here, *Digitaria royleana*, *Cynodon dactylon* and a few others continue to grow for the dry seasons as the salinity does not increase very much.

The foot tracks are covered with *Paspalidium flavidum*, va ; *Tribulus terrestris*, f ; *Sporobolus wallichii*, a ; *Cynodon dactylon*, f ; and *Euphorbia* spp., of. Only the first two elements disappear during the dry seasons.

Such a grassland does not ordinarily develop in shade, but, under the mango groves in the south of the grounds where direct light is obtained in the form of moving sunflakes, a grassland of *Imperata cylindrica* is obtained. The species remains in a depauperate form on account of frequent grazing and scraping. The soil has an average pH value of 7·21 and is well nitrified (= 2). The following associate species are found here : *Paspalidium flavidum*, *Paspalum scorbiculatum*, *Bothriochloa pertusa*, *Desmodium gangeticum*, *D. parvifolium*, *D. triflorum* and *Rungia parviflora*.

There is a very sparse growth at the base of the tree boles. This may be so on account of the seeds being washed off by the rainwater

dripping along them, and also presumably due to a large population of ants which live on the tree and feed upon the grass seeds. *Oplismenus burmanni*, a ; *Evolvulus nummularius*, f ; and *Sida veronicæfolia* are the only species which easily creep up to these situations.

9. *Sir Gangaram Canal*

A beautiful pucka canal, named after Sir Gangaram, was built in the centre of the University, in 1936. It is a fifty-feet wide structure, and runs in an oval shape around the temple ground for a little more than three furlongs in total length. It is bound by six-feet high walls, and the bottom has a slope of 1½ feet towards the middle. Some sand was deposited on it as the bottom became slippery for bathers on account of algal growth. But it all accumulated in the middle deeper part due to the slope. After working it for three years when it was served by tube wells fitted with electric pumps, the canal was abandoned as the filling was found to be too expensive. Now in the dry condition, the bottom has cracked at numerous places. The sand and the cracks have provided landing grounds for plant colonists. Of these *Saccharum munja* is very aggressive and destructive to the canal bottom. Its rhizomes growing out of the sand run higher up at the sloping bottom and send down roots on coming across a little hole. Here the plant grows in a tussock cracking up the cemented substratum extensively, and sends out some more rhizomes to repeat the process elsewhere. The cracks are further widened by a host of species among which *Tridax procumbens* is abundant. Undisturbed by th biotic factors, this vegetation is rapidly growing on the ruins of the canal (Fig. 3). It has a luxuriant aspect on the gray sand deposits during the rainy season, but it is abruptly reduced in the following dry seasons when the few remaining drought-enduring species alone are found rooted to the crevices.

The strip of sand lying in the middle is 4–6 feet wide and about 6 inches deep. Rainwater collecting here runs into two pools situated at the ends of the canal. When enough has accumulated to fill them up during the rainy season, the strip of sand is also covered with it at the middle, which gets exposed only at longer intervals of drought. Even so, and despite the thinness of the deposit, the sand remains almost continuously saturated with water in the season as little could be lost by percolation—there being the cemented bottom. The high moisture content of the sand sustains a growth of closed grass-sedge community which reduces surface evaporation and improves the water-retaining capacity of the substratum by adding humus to it. It has actually turned gray on the same account. Its moisture content fluctuates between 28·5–2·80% from July to September. In the dry seasons it goes down to 0·8–0·23%. The cement and the mortar, weathering out into the sand, make it highly alkaline and saline. The pH value is found to be between 8·02 and 8·36, and the carbonate content = 4. Its nitrifying capacity is low being locally perceptible upto 1.

The rainy season vegetation on the sand shows out a central wet zone which remains covered with water for a longer time and

a marginal drier zone. The central zone is characterised by the following growth : *Ammania baccifera*, o ; *Alternanthera sessilis*, o ; *Cyperus* spp., o ; *Echinochloa colona*, d ; *Fimbristylis podocarpa* and *F. diphylla*, o ; *Juncellus pygmæus*, lf ; *Paspalidium flavidum*, lf; *Saccharum spontaneum*, o ; *S. munja*, o ; *Eragrostis* spp., cd–la ; and *Cyperus rotundus*, la. Only the last four species live till the month of January when they are joined with a growth of *Cynodon dactylon*, o ; *Portulaca oleracea* and *P. quadrifida*. By the end of April only these three, with *Saccharum munja* and a few plants of *Evolvulus alsinoides* are found in this zone.

The marginal vegetation on the sand has the followiig composition : *Aristida adscenscionis*, r–o ; *Achyranthes aspera*, o ; *Cyperus compressus*, lf ; *Paspalidium flavidum*, lf ; *Cyperus rotundus*, la ; *Eragrostis* spp., f–la ; *Eleusine ægyptica*, o ; *Justicia quinqueangularis*, lf ; *Saccharum spontaneum*, o ; *Sporobolus* spp., f ; and *Scoparia dulcis*, r during the rainy season ; the last seven species and *Alysicarpus monilifer*, r–o ; *Portulaca* spp., lf ; *Euphorbia prostrata*, o and *Vernonia cinerea*, o—during the cold season, and only these four continuing till the end of the hot season. *Saccharum munja*, f and *Cynodon dactylon*, o are found throughout the year.

At one place in the dry canal, water has been trickling from a leaking pipe which ran over it to supply for the construction of the temple. Here a more lasting and closed plant community, consisting chiefly of the grasses and the sedges, has developed (Fig. 4). It has substantially modified the characters of the substratum in as much as the pH value has gone down to 7·86 and the sand has become darker and softer with humus. The vegetation consists of : *Echinochloa colona*, la ; *Fimbristylis* spp., o–la ; *Juncellus pygmæus*, lf ; *Ishcæmum rugosum*, o during the rainy season, *Alternanthera sessilis*, lf ; *Blumea lacera*, o ; *Eragrostis* spp., o–lf ; *Justicia quinqueangularis*, f–la growing in the rainy and the cold seasons, *Sphæranthus indicus*, r, coming up in the cold season but continuing till the hot season, and *Cyperus* spp., f–la ; *Cynodon dactylon*, f ; *Eclipta alba*, o ; *Saccharum munja*, f and *Scoparia dulcis*, r, grow for the whole of the year. Most of these plants would not be found on the sand but for its higher moisture and humus content.

Wherever a little soil from outside has accumulated on the bottom of the canal, a very different colony of plants is to be found in the rainy season. The commonest species are : *Tephrosia purpurea*, *Corchorus acutangularis*, *Cassia tora* and *Urochloa reptans*. *Calortopis procera* grows for the whole year on thicker deposits of soil.

The cracks on the bottom are inhabited by *Saccharum munja*, d ; *Tridax procumbens*, *a* ; *Cynodon dactylon*, o ; and *Sporobolus* spp., f ; *Eleusine indica* and *E. ægyptica*, f ; *Eragrostis* spp., f ; *Scoparia dulcis*, o, during the rainy and the cold seasons, and *Portulaca* spp., lf, in the dry seasons.

Grasses like *Bothriochloa pertusa*, *Dichanthium annulatum* and species of *Digitaria* grow only on the sand and soil held on the tussocks

of *Saccharum munja* forming a distinct plant cummunity. These plants seem to be susceptible to the high carbonate and calcium content of the canal bottom. The other species as found on the pucka substratum must then be strongly calcicolous.

10. *Weeds of cultivated lands*

A good part of the University grounds is under cultivation. Almost all the principal crops are raised here. The typical weeds of these as associated with the rainy season crops (Kharif) and the cold season crops (Rabi) are listed below. The weeds are well equipped for distribution and growth under the cultural operations and many of them are exclusive to the areas, being ousted from elsewhere by the native species which are more aggressive there.

KHARIF

**Cyperus rotundus*
C. compressus
Juncellus pygmæus
Pycerus pumilus
Scirpus squarrosus
Fimbristylis diphylla
Digitaria sanguinalis
D. royleana
Eleusine aegyptica
E. indica
**Eragrostis tenella*
E. pilosa
Sporobolus wallichii
**Desmostachya bipinnata*
Bonnaya brachiata
B. veronicæfolia
Vandellia crustacea
Oldenlandia paniculata
O. corymbosa
Trianthema monogyna
**Portulaca oleracea*
**Convolvulus arvensis*
Cleome viscosa
Gynandropsis pentaphylla
Physalis minima
Corchorus acutangularis
Sesbania aculeata
Lochnera pusilla
**Aerua scandens*
Digera arvensis
**Striga euphrasiodes*
**Leucas aspera*

RABI

Asphodelus tennuifolius
Chenopodium album
Euphorbia dracunculoides
Anagallis arvensis
Saponaria vaccaria
Vicia sativa
Melilotus alba
M. indica
Medicago lupulina
Lathyrus aphaca
L. sativa
Amarantus spinosus
A. viridis
Argemone mexicana
Launea nudicaulis
Canscora decussata
Echinops echinatus
Volutarella divaricata
Orobanche ægyptica
O. cernua
Blumea spp.
Solanum nigrum

Also those marked with an asterisk (*) under Kharif

The weeds of the rice fields are those generally found on low-lying lands. The characters of such habitats have been described by Misra (1946). The more important species are listed below :

Ammania baccifera
A. peploides
Aponogeton spp.
Caesulia axillaris
Cyanotis axillaris
Cyperus digitatus
C. exaltatus
Echinochloa colona
E. crus-galli
Glossostigma spathulatum
Hemarthria compressa
Hydrolea zeylanica
Hygrophila polysperma
Ischæmum rugosum
Ludwigia parviflora
Manisuris granularis
Mariscus compactus
Oryza sativa
Panicum proliferum
P. humile
P. psilopodium
Paspalidium geminatum
Sesbania aculeata

When the fields are dry and the crop has been removed, the following species come up :

Cynodon dactylon
Dichanthium annulatum
Eragrostis interrupta
Grangea maderaspatana
Hydrolea zeylanica
Iseilema laxum
Scirpus articulatus
S. michælianus
Sphæranthus indicus

III. Discussion

The vegetation of the grounds owes its existence to human activities. These are chiefly: scraping and grazing, construction of buildings, roads, canals, etc., traffic and cultivation, producing the different types of communities as described in the text. The grounds are frequently denuded of the plant cover, and soil conditions are altered by these operations which also play a continuous selective role on fresh invasions and colonisations, and induce quite often variations in the form of the species. This is how the communities are actually shaped. Big drifts in soil moisture and temperature during the year are mainly responsible for the contrasting seasonal aspects. While batches of annuals come up and die the perennials resume growth, show habit variations and may even lose their shoots with a change of the seasons. The component species of the community growing together but at different stages of their life-cycle, add to the diversity of a highly heterogeneous assemblage of plants. Indeed, the vegetation of a locality in two different seasons is more unlike than that of two dissimilar localities at the same time. But, since the seasons with all their effects are recurrent, the vegetation of any locality has to be viewed as a whole throughout the year. It is only in this way that a changing habitat with the changing vegetation of a locality can be brought together in a line, through the seasons. For the characterisation of such a plant community, the perennials should especially be taken into account, though the annuals may become dominant at times as in more denuded areas.

In a study of the low-lying lands Misra (1946) took a different view in proposing a 'hydrosere' and a 'xerosere' as proceeding at the same place but at different times of the year, where entirely different plant communities grow in water and on the dried up bottom each year depending not so much in the former case on seasons as on the depth of water. But here in the present case, a matrix vegetation, howsoever small, consisting of a few perennials is always found on the ground throughout the year, despite the diversity of the seasons. Hence different lines of succession need not be drawn in this case; even so, it becomes unthinkable in a higher community, such as a forest where a situation like this does not arise as the exigencies of the seasons are mainly met by changes in the shoots of the dominant trees, and here the destructive biotic factors become subordinate to the growing community.

The status of the meadow vegetation in this area is therefore a disclimax in the terms of Weaver and Clements (1929). The meadow associes is characterised by the following species: *Dichanthium annulatum*, *Indigofera enneaphylla*, *Boerhaavia diffusa*, *Euphorbia hirta*, *E.* spp., *Cynodon dactylon*, *Evolvulus alsinoides*, *Convolvulus pluricaulis*, *Justicia diffusa* and locally *Rungia* sp.

IV. Summary

The vegetation as found in the various habitats of the grounds of Benares Hindu University, covering an area of about three square

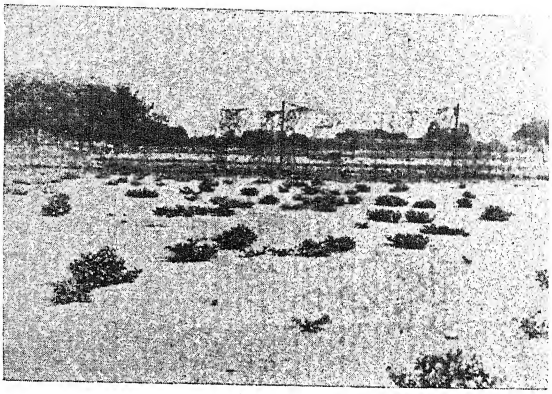

FIG. 2

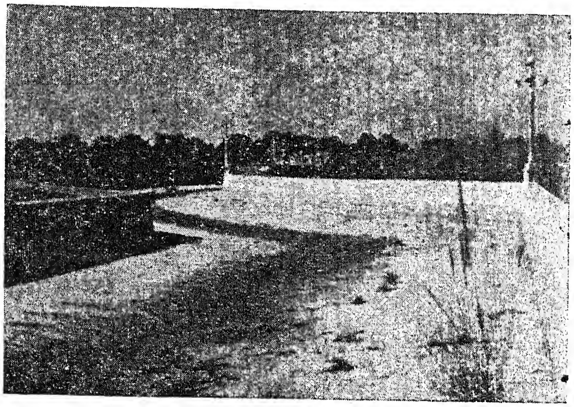

FIG. 3

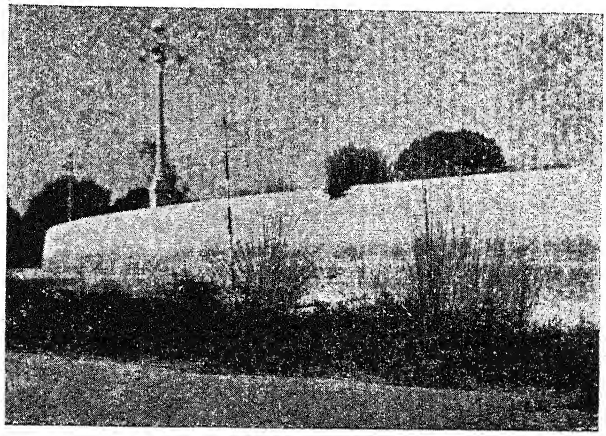

FIG. 4

R. MISRA—

AN ECOLOGICAL STUDY OF THE VEGETATION OF THE BENARES HINDU UNIVERSITY GROUNDS

miles, is described. The different factors controlling its growth in the three seasons have been analysed with a special study of the soil.

Many facts of ecological importance and emerging problems are noted in the study.

It is concluded that the meadow vegetation which is largely controlled by human activities is a disclimax in this area.

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ON THE OCCURRENCE OF MICROSPORES IN SOME CENTRIC DIATOMS OF THE MADRAS COAST*

By R. Subrahmanyan, M.Sc.

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There have been several records of microspore-formation among Centric Diatoms. Fritsch (1935, pp. 633–38) and Smith (1933, pp. 205–6) have given a brief account of all the various records of microspores by different workers and the different views expressed by these authors regarding the nature of these microspores. Since then, a few more records of microspore-formation have been made (Majeed, 1935; Gross, 1937/38; and Braarud, 1939). Conflicting opinions have been expressed regarding the exact nature and role of these microspores in the life-history of the Diatom, *viz.*, (1) that they represent the gametes of the Diatom, (2) that they are not gametes but asexual reproductive bodies intended for the multiplication of the Diatom, and (3) that they are not reproductive structures of the Diatom at all, but are only foreign parasites or abnormal products of the Diatom cell playing no part in its life-history. The writer does not propose to go into the question of the nature and role of these microspores here. He merely wishes to record here some cases of microspore-formation that he came across while investigating the marine plankton Diatoms of the Madras coast. There does not appear to be any record of microspore-formation in the marine Diatoms of India so far. Altogether this phenomenon was observed by the writer in six forms from the Madras Coast, viz., *Coscinodiscus* sp., *Actinocyclus Ehrenbergii* Ralfs, *Chætoceros Lorenzianus* Grunow, *Bellerochea malleus* (Brightwell) Van Heurck, *Biddulphia mobiliensis* Bailey and *Cerataulina Bergonii* Peragallo. Of these, microspore-formation has already been recorded from outside Indian waters in *Coscinodiscus* (Murray, 1896; Karsten, 1928; Hofker, 1928; and Schmidt, 1931), *Chætoceros* (Gran, 1904; Schiller, 1909; Pavillard, 1914; Henckel, 1925; Gross, 1937/38; and Braarud, 1939) and *Biddulphia* (Bergon, 1907 and Schmidt, 1927, 1928, 1929 and 1933). As regards the remaining genera, viz., *Actinocyclus*, *Bellerochea* and *Cerataulina*, this is the first record of microspore-formation in them.

1. *Coscinodiscus* sp.

In this Diatom, a cell with four rounded bodies was observed at about 12–50 p.m. on 2–12–1942, and was kept under observation in a hang-drop culture. These four bodies, by division (Text-fig. 1), formed eight bodies which by further division gave rise to sixteen bodies by about 1 p.m. (Text-figs. 2 and 3); and by 2 p.m. by

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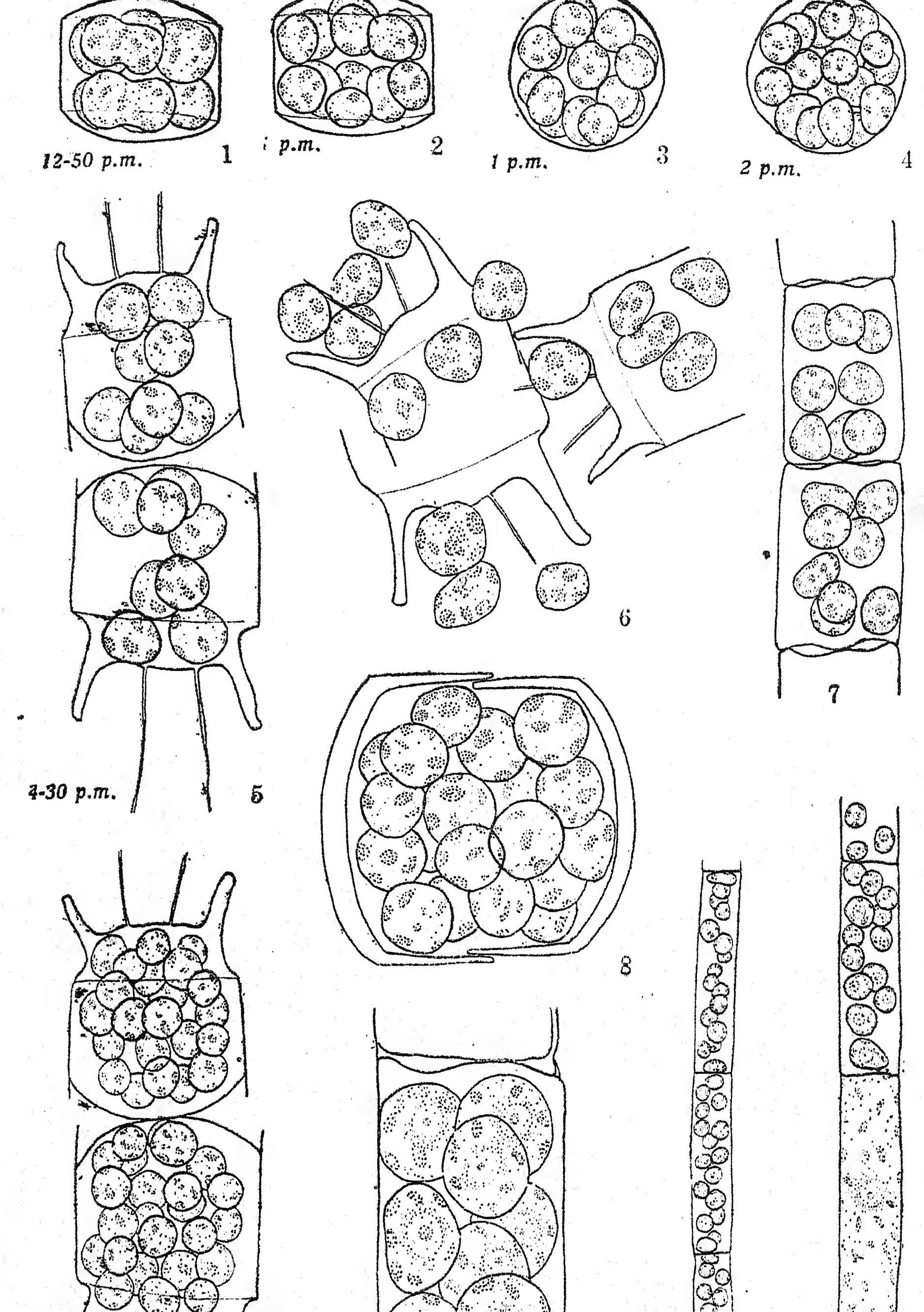

Text-figs. 1 12.—Figs. 1–4. *Coscinodiscus* sp.—Fig. 1. Observed on 2-12-1942 at about 12–50 p.m. Note two of the bodies dividing, some already divided. Figs. 2

and 3. Girdle and valve views of cell showing 16 bodies. All bodies not drawn; about 1 p.m. Fig. 4. 32 Microspores in the cell, about 2 p.m. All spores not drawn. Figs. 5 and 6. *Biddulphia mobiliensis.*—Fig. 5. Observed on 2-10-1940 at about 4–30 p.m. Note 8 bodies in each of the two 'sporangia' of the cell. Fig. 6. From culture: spores inside and outside the cell. Fig. 7. *Bellerochea malleus*, observed on 5-3-1940. Note 2 cells each showing 8 microspores. Fig. 8. *Actinocyclus Ehrenbergii*, observed on 12-1-1941. Cell with 32 microspores all spores not shown. Fig. 9. *Biddulphia mobiliensis*, same cell shown in Fig. 5 at about 5·40 p.m. Each 'sporangium' with 32 microspores, all not drawn. Fig. 10. *Bellerochea malleus*, observed on 5-3-1940, 8 microspores in the cell. Figs. 11 and 12. *Cerataulina Bergonii*, observed on 24-3-1941. Chains showing microspore-formation. One vegetative cell shown in Fig. 12. Figs. 1-4, ×330; Figs. 5 & 9 ×690; Figs. 6 & 10, ×1065; Figs. 7 & 8, ×650; and Figs. 11 & 12, ×225.

another division about thirty-two bodies were formed (Text-fig. 4). These bodies were round and each showed a few chromatophores. No cilia could be observed in any of them though they were very carefully examined. The cell was kept under observation for a long time to observe the liberation of these spores. They did not escape from the cell, but finally they degenerated and died. Microspores have been recorded previously in this genus by Murray (1896), Karsten (1928) and Hofker (1928).

2. *Biddulphia mobiliensis* BAILEY

In one of the cells of this Diatom eight rounded bodies were observed in each of the two 'sporangia' which had previously formed in it (Text-fig. 5; Pl. IV, Fig. 1), at about 4–30 p.m., on 2–10–1940. The cell was kept under observation in a hang-drop culture. The rounded bodies in each 'sporangium' then divided and sixteen were formed. Each one of these sixteen bodies again divided and ultimately at about 5–40 p.m. thirty-two spores were formed in each 'sporangium' (Text-fig. 9; Pl. IV, Fig. 2), so that on the whole sixty-four spores were formed in each cell. The spores did not show any further division. Each spore showed a few chomatophores and a nucleus which could be seen on very careful examination. The spores were observed to exhibit some amœboid movement. Though they were kept under observation for a long time they did not escape out of the cell, but finally degenerated and died. These observations agree with those of Bergon (1904) on the same Diatom up to the formation of thirty-two cells in each 'sporangium'. But Bergon observed finally the liberation of these spores as swarmers with two laterally attached cilia. This liberation of the spores as already mentioned was not observed by the writer in the present Diatom.

Again, in some of the old cultures of the Diatom, the writer observed a number of rounded bodies inside and outside the cells (Text-fig. 6). They were isolated into fresh culture media and kept under observation; but they did not show any further development in any one of the cultures. After some time they degenerated and died.

3. *Chætoceros Lorenzianus* GRUNOW

A few chains of this Diatom showing microspore-formation were met with in the plankton on 2–10–1940. Here each cell of the chain

showed two 'sporangia' in each of which were seen four spores (Pl. IV, Figs. 4 and 5). The spores were somewhat pear-shaped and showed a few chromatophores inside. No cilia could be seen on any of them. They were kept under observation for a long time for watching their liberation. They did not escape out, but finally degenerated and died. The microspores observed by the writer in this Diatom do not at all resemble the microspores recorded by Schiller (1909, Pl. XVI Figs. 10 and 11) in the same species, but resemble very closely the microspores of *Chætoceros decipiens* as recorded by Gran (see Fritsch, 1935, p. 634; figs. 213 I & J). It may also be mentioned here that Schiller observed two types of microspores in this Diatom, small and large ones, so also did Gran in *Ch. decipiens*. But such large and small ones were not observed by the writer.

4. *Actinocyclus Ehrenbergii* RALFS

A cell containing about thirty-two spores was observed on 12–1–1941 and this was kept under observation as in the previous cases. The spores were round and showed a few chromatophores and a nucleus. The spores did not escape out of the cell but finally degenerated and died. Microspore-formation does not appear to have been recorded in this genus previously.

5. *Bellerochea malleus* (Brightwell) VAN HEURCK

A chain of a few cells containing microspores was observed on 5–3–1940 (Text-figs. 7 and 10). Each cell of the chain showed eight microspores and these were similar to those observed in the previous forms. They were round and showed a few chromatophores and a prominent nucleus. The microspores did not escape out but died after some time. Microspore-formation does not appear to have been recorded previously in this genus.

6. *Cerataulina Bergonii* PERAGALLO

Several chains of cells showing microspores were met with in the plankton on 24–3–1941 (Text-figs. 11 and 12). Each cell of the chain showed about sixteen microspores. The number of spores in some of the cells was slightly less, but, in these cases some of the round bodies were larger than the others and probably represented protoplasts about to divide. Microspore-formation does not appear to have been recorded in this genus also.

SUMMARY

Microspore-formation was recorded in six marine Centric Diatoms from the Madras coast, viz., *Coscinodiscus* sp., *Actinocyclus Ehrenbergii* Ralfs, *Chætoceros Lorenzianus* Grunow, *Bellerochea malleus* (Brightwell) Van Heurck, *Biddulphia mobiliensis* Bailey and *Cerataulina Bergonii* Peragallo. In *Chætoceros* and *Bellerochea* eight, in *Cerataulina* sixteen, in *Coscinodiscus* and *Actinocyclus* thirty-two and in *Biddulphia* sixty-four microspores were observed. This is the first record of microspore-formation in the genera *Actinocyclus*, *Bellerochea* and *Cerataulina*.

The writer wishes to express his indebtedness to Prof. M. O. P. Iyengar, M.A., Ph.D. (Lond.), F.L.S., for his guidance and help throughout the course of this work. His sincere thanks are also due to the authorities of the University of Madras for the award of a research scholarship during the tenure of which this investigation was carried out.

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EXPLANATION OF THE PLATE

Figs. 1 & 2. *Biddulphia mobiliensis.*—Fig. 1. Cell observed at about 4–30 p.m. Note 8 bodies in each 'sporangium' of the cell. Fig. 2. The same cell at about 5–40 p.m. Note 32 microspores in each 'sporangium'. ×640.

Fig. 3. *Bellerochea malleus.*—Note 8 microspores in each cell of the chain. ×750.

Figs. 4 & 5. *Chætoceros Lorenzianus.*—Fig. 5. A chain of cells showing microspore-formation. ×400. Fig. 4. A few cells of the chain under higher magnification. Note 4 microspores in each of the two 'sporangia' of the cell. ×1000.

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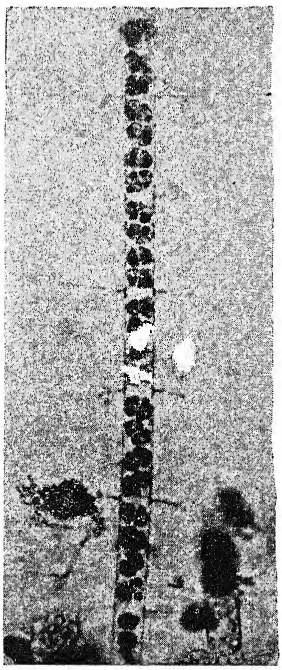

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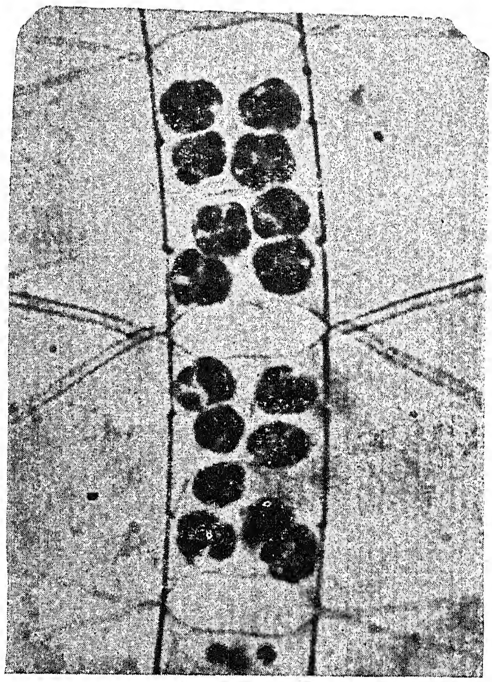

5

R. SUBRAHMANYAN—

ON THE OCCURRENCE OF MICROSPORES IN SOME CENTRIC DIATOMS OF THE MADRAS COAST

FEMALE GAMETOPHYTE OF *ACALYPHA TRICOLOR*

BY B. G. L. SWAMY AND B. P. BALAKRISHNA

IT is well known that the family Euphorbiaceæ consists of certain genera that show different types of embryo-sac development. Though considerable amount of work has already been done on the embryology of the members of the family, our knowledge to-day is by no means complete. Particularly so are genera like *Mallotus*, *Acalypha*, etc., whose different species show different types of organisation of the embryo-sac both during development and maturity. For example, *Mallotus japonicus* (Ventura, 1934) develops its female gametophyte according to the *Drusa*-form, while *M. philippinensis* (Thathachar, 1944) develops its embryo-sac according to the *Penæa*-form. Again *Acalypha australis* (Tateishi, 1927) shows the *Penæa*-form; a species of *Acalypha* according to Arnoldi (1912) also shows the same form; *A. indica* (Maheshwari and Johri, 1940), an intermediate organisation between *Penæa*-form and *Plumbago*-type, which formation has been termed by the authors as the "*Acalypha indica*-form", while *A. lanceolata* (Thathachar, 1944) shows the *Peperomia hispidula*-form (Johnson, 1914). Hence an investigation of the remaining species of these genera becomes very important. With this idea in mind and also with a view to see if a plant subjected to extreme cultivation shows any anomalies in the development of its female gametophyte, *Acalypha tricolor* was investigated. The results of the investigation are embodied in this paper.

Acalypha tricolor is a shrub, cultivated very commonly as a horticultural plant for its variegated foliage. A considerable percentage of flowers are sterile, but the normal ones produce viable seeds. Material for study was collected from a private garden and slides were prepared according to customary methods.

The young ovule has two integuments, the outer one soon extending beyond the inner one to constitute the micropyle. Later the nucellus grows out of the inner integument in the form of a beak until the obturator comes in contact with it (Fig. 1). Though the presence of a single archesporial cell is the rule, two or three such cells were rarely seen. The primary parietal cell divides in all planes and contributes towards the formation of the nucellar beak.

The megaspore-mother cell after enlarging (Fig. 2) divides meiotically, the four megaspore nuclei usually occupying the four poles (Fig. 3). Each nucleus in this very position divides twice to form a group of four nuclei, three of which organise into cells and one nucleus remains free. The free nuclei belonging to each quadruple group migrate towards each other and fuse to form the secondary embryo-sac nucleus (Figs. 5 and 6). Of the four groups of three

cells, the one situated near the micropyle usually bears a resemblance to the egg apparatus in shape, size, vacuolation and function. However, this distinction is not only frequently absent from the micropylar group, but is often seen in the other three groups as well, in varying degrees. But always the egg of the micropylar group alone is fertilised. The position of the two lateral groups is not always fixed ; commonly

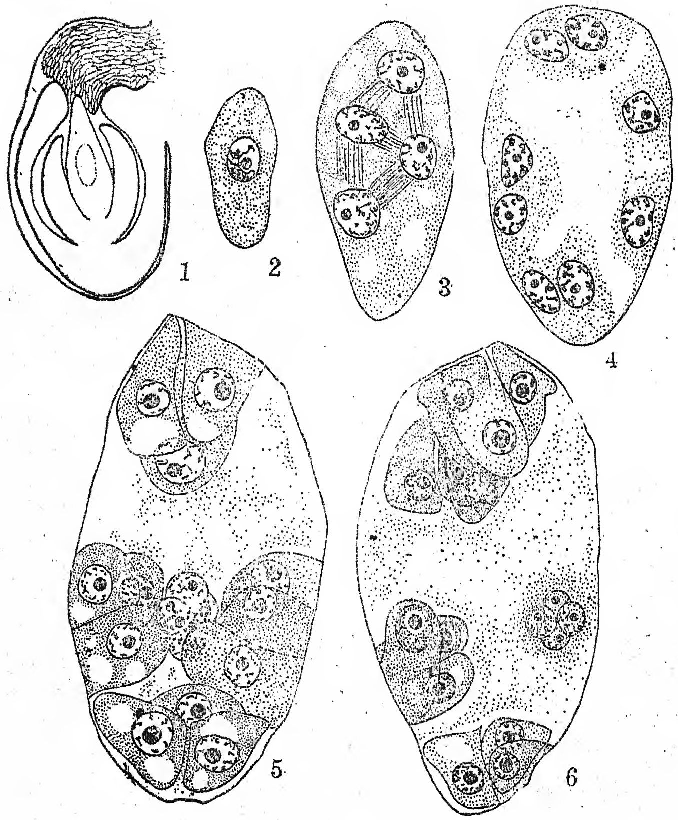

Fig. 1. Longitudinal section of one locule showing the disposition of the ovule and obturator, × 80. Fig. 2. Megaspore mother cell, × 780. Fig. 3. 4-nucleate stage of the embryo-sac, × 780. Fig. 4. 8-nucleate embryo-sac, × 780. Figs. 5 and 6. Mature 16-nucleate embryo-sacs ; for explanation see text, × 900.

they occupy the equatorial region of the embryo-sac, opposite to one another ; frequently they are found on either side of the antipodal group (Fig. 5) ; in a few other cases they are seen to be disposed anywhere towards the periphery between the antipodal and micropylar groups (Fig. 6). Whatever may be the individual position of the respective group other than the micropylar one, they degenerate after fertilisation. The cause of the varied positions of the lateral groups was traced back to the respective disposition of the particular

megaspore nuclei at the four-nucleate stage of the gametophyte and no evidence for their displacement after the formation of the quadruple group could be seen.

CONCLUSION

Acalypha tricolor is a plant subjected to extreme cultivation under horticultural practice by clonal propagation. The embryo-sac develops in a tetrasporic manner and its mature organisation conforms to the well-known *Penæa*-form. The details and sequence of development differ in no fundamental manner from the *Penæa*-form of embryo-sacs, reported in various species of naturally growing Angiosperms. Even the varied position of the lateral groups of nuclei within the embryo-sac does not seem to be a point in favour of the commonly held view that it may be due to cultivation, because this phenomenon is often met within naturally occurring plants also. It has been seen to a marked degree in several wild species of *Peperomia* now being investigated by one of the authors.

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NITROGEN METABOLISM IN RICE LEAVES

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THE importance of nitrogenous manures to rice plants have drawn the attention of the plant physiologists from the later part of the last century. Earlier works are mainly on the effect of different nitrogenous manures, specially on the relative importance of ammonium sulphate and sodium nitrate and on the absorption of nitrogen at various stages of life. Dastur and Malkani[2] have reviewed all the previous works on rice nutrition in response to different nitrogenous manures studied by Kellner, Nagaoka, Aso and Bahadur, Krauss, Trelease and Paulino, Daikhura and Imreski, Kelley, Harrison, Espino, Shive, Wills and Carrears, and have shown that the rice plant prefers ammonium salt in earlier phase and nitrate salts in later phase of growth. In order to determine the best time for applying nitrogenous manures the rate of absorption of nitrogen has been studied by Kelley and Thompson, Gile and Carreo, Herreo, Suzuki, Sen, and Sahasrabuddhe by analysing the distribution of nitrogen in different parts of the plant at different stages of growth. Sahasrabuddhe[4] has reviewed these works. All workers observed uniform increase in nitrogen content throughout the life but Sahasrabuddhe found two distinct phases of increased rate of absorption, first just after transplantation and the second on the onset of flowering.

All the workers, who have studied the nitrogen content at different stages of growth found that the absorbed nitrogen mainly remains in the leaves. But little attention has been paid to ascertain how the absorbed nitrogen is metabolised in the leaves, a knowledge of which is necessary to understand the physiological processes of the plant. Interesting correlations have been observed by Sircar and Sen[5] between phosphorus deficiency and nitrogen metabolism. The present paper deals with the nitrogen metabolism in the successive mature leaves of rice grown in pots under optimum cultural conditions.

EXPERIMENTAL PROCEDURE

Rice seeds of var. Bhasamanik were selected for uniformity of size and colour, sterilised with 0·2 per cent. formalin and sown in seed beds in field. When the seedlings were 6 weeks' old with 6th or 7th leaf unfolding, they were transplanted to earthenware pots 10" diam. containing a mixture of fine soil and ⅛th part of cowdung manure, each pot having one seedling. The pots were kept inside cemented tanks and water level up to the height of the plants was maintained during the course of the experiment. As each leaf on the main axis reached maturity, it was sampled at 6–30 a.m. and taken to the laboratory in glass tubes lined with moist filter-paper and analysed immediately for the nitrogen fractions. Leaf samples of 3rd, 4th, 5th and 6th

leaves were taken from seed beds, while those of 7th to 15th leaves were taken from the pots after transplantation.

The leaves were bisected longitudinally, cut into small bits and weighed. One half was dried at 70° C. for 24 hours and finally at 100° C. for 30 min., powdered in mortar and total nitrogen was estimated in the micro-Kjeldahl apparatus according to Pregl.[7] Reduction of nitrate was carried out by the reduced iron method of Pucher, Leavenworth and Vickery.[8] The other half was thoroughly ground in a mortar to a paste with phenol-water. The extract was filtered through paper pulp and made upto 50 c.c. with several washings of distilled water by using filter pump. Frothing was prevented by adding a few drops of capryl alcohol. Protein was removed from the extract by adding 50 per cent. solution of trichloroacetic acid in the proportion of 1 c.c. acid to 19 c.c. extract and filtering. From the filtrate total crystalloid nitrogen was estimated as before by micro-Kjeldahl method after reduction of nitrate. Protein nitrogen was calculated by the difference between the total nitrogen and crystalloid nitrogen content. Total amino-nitrogen was determined by adaptation of Brown's[1] modification of Sorensen's formol-titration method. Amide nitrogen was estimated by hydrolysing the protein-free extract with sulphuric acid and estimating the ammonia produced by Wolff's method.[9] Regarding amide nitrogen the assumption is made that all amides in the plant exist in the form of asparagine and the absolute values of amino acids are estimated from the difference between total amino and amide figures as has been mentioned by Sircar and Sen.[5] The figures for residual N includes all soluble nitrogen fractions not estimated in any of the above fractions.

Experimental Results

The nitrogen fractions in the successive mature leaves are presented as percentage of dry weight in Table I and graphically represented in Fig. 1 and as percentage of total leaf nitrogen in Table II.

TABLE I

Nitrogen fractions expressed in percentage of dry weight

Leaf No.	Total N	Protein N	Crystalloid N	Total Amino N	Amide N	Amino N	Residual N
3	3·3845	2·7113	0·6732	0·07367	0·05252	0·02115	0·54501
4	2·7355	2·4130	0·3225	0·05848	0·03229	0·02519	0·23083
5	2·4530	2·1702	0·2828	0·05006	0·02752	0·02254	0·20422
6	2·153	1·8773	0·2757	0·03298	0·01631	0·01667	0·22651
7	2·863	2·4766	0·3864	0·11810	0·09003	0·02810	0·17827
8	2·853	2·5469	0·3061	0·07750	0·03959	0·03816	0·18901
9	2·533	2·3127	0·2203	0·05244	0·04089	0·01155	0·12697
10	2·510	2·3062	0·2038	0·04573	0·01965	0·03618	0·13842
11	2·122	1·9555	0·1665	0·0396	0·01732	0·02228	0·10958
12	2·080	1·9226	0·1574	0·01573	0·00347	0·01226	0·12820
13	2·1645	1·9870	0·1875	0·02678	0·00427	0·02251	0·15645
14	1·788	1·5733	0·2145	0·1083	0·02029	0·08801	0·08591
15	1·875	1·6849	0·1901	0·06792	0·0587	0·00922	0·06348

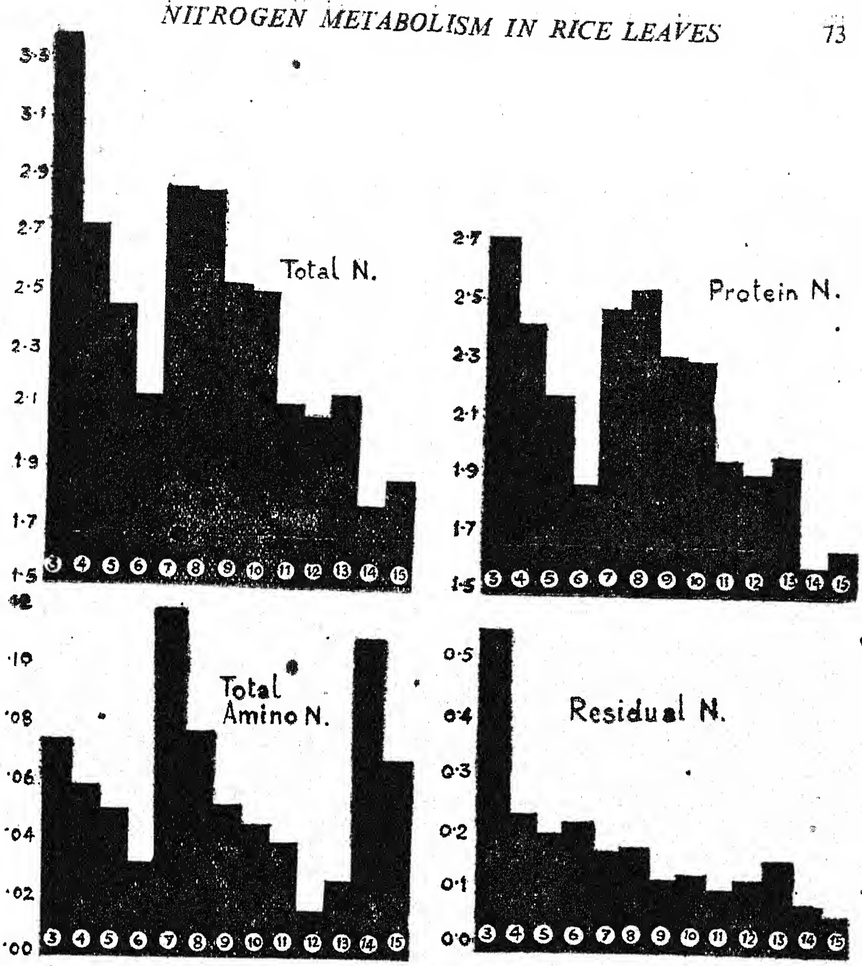

Fig. 1. Nitrogen fractions in the successive mature leaves in rice expressed as percentage of dry weight.

TABLE II

Nitrogen fractions expressed as percentage of total nitrogen

Leaf No.	Protein N	Crystalloid N	Total Amino N	Amide N	Amino N	Residual N
3	80·13	19·67	2·177	1·552	0·625	16·141
4	88·10	11·90	2·138	1·180	0·958	8·582
5	88·67	11·33	2·041	1·120	0·921	8·169
6	91·33	8·16	1·532	0·757	0·774	5·881
7	86·48	13·52	4·122	3·143	0·979	6·255
8	89·24	10·76	2·716	1·388	1·328	6·656
9	91·28	8·72	2·070	1·614	0·356	5·356
10	91·90	8·10	1·822	0·7829	1·0391	5·495
11	92·12	7·88	1·866	0·8156	1·0506	5·1984
12	94·54	5·46	0·756	0·1668	0·5893	4·5371
13	91·81	8·19	1·237	0·1973	1·0397	6·7557
14	87·96	12·04	6·056	1·109	4·947	4·875
15	89·91	10·09	3·622	3·060	0·562	3·408

The nitrogen content as percentage of dry weight decreased in the successive leaves. In the 7th leaf, the first mature leaf developed after transplantation, the nitrogen content increased greatly and almost the same level was maintained in the next leaf. From the 8th leaf onwards a continual fall in nitrogen is seen with a slight increase in the 13th and 15th leaves.

The protein N varied directly as the total N in the successive leaves. It is interesting to note that protein N expressed as percentage of dry weight diminished, while as percentage of total N. increased in the successive leaves. Nitrogen exists mainly as protein, the highest protein level of 94 per cent. being observed in the 12th leaf.

Considerable accumulation of amide N was noticed in the 7th leaf, *i.e.*, after transplantation and again in the 14th and 15th leaves. The quantity of amide N and amino N in rice leaves was found to be very low. The concentration of amino N was generally about 0·1 per cent. of the total N. In the earlier leaves the amino N. content were more or less the same, but after transplantation a rise was noticed in the 7th and 8th leaves and a great irregularity in its concentration is represented in the successive leaves. At the time of ear emergence, *i.e.*, in the 14th leaf an increase in amino N was noticed which is again considerably reduced in the next leaf. A high concentration of residual N was noticed in the 3rd leaf, and in the successive leaves its concentration gradually decreased.

Discussion

In rice plant total Nitrogen content gradually increases after germination with the development of plant. After transplantation plants require some time to settle in the new environment and this is followed by a rapid absorption of nitrogen and vigorous growth in tillering and height. The value of total nitrogen in percentage of dry weight, however, falls with age, reaching a low figure at the time of flowering. Sircar and Sen[5] observed that a high percentage of nitrogen in the mature leaves before ear emergence is associated with the formation of unfertile spike and even to the suppression of ear. The 7th leaf developed after transplantation. A marked increase in its nitrogen content was observed over the next lower leaf, sampled in seed-bed, though the values were gradually diminishing from 3rd to 6th leaf. This suggests a rapid uptake of nitrogen after transplantation as observed by previous workers. The gradual fall in nitrogen level in the successive leaves is more due to the fact that non-nitrogenous dry matters increase much more rapidly. That increase of dry matter in the successive leaves is associated with higher sugar concentration was observed by Ghosh[2] working under similar concentration, and that the rate of sugar-production increased in the later leaves. Nitrogen is mainly present as protein, which gradually increased till the 12th leaf. High protein content of the later leaves suggest increased metabolic activity synthesising the major part of nitrogen to protein. The fall of protein content in the last two leaves (the 14th leaf was sampled when the ears were emerging and the 15th leaf in the milky stage of ear) seems due to the fact that at this stage a considerable amount of protein is

translocated to the rapidly growing ear. One of the most important factor for protein loss in the mature leaves is the formation of young leaves and inflorescences, which act like sink and increase the rate of translocation of nitrogen from the leaves below (Petrie, 1937). With the decrease of protein N at this stage a considerable increase in amino and amide N support the rapid translocation from these leaves. High residual N content, which generally represents the nitrate fraction, in the 3rd leaf is difficult to interpret as Dastur and Malkani[2] observed that rice plants absorb mainly ammonium ion at the earlier stages, and further fractionation is necessary to determine its nature.

Summary and Conclusions

The paper deals with the nitrogen fractions in the successive leaves of rice grown in soil under optimum cultural conditions. A gradual decrease in the concentration of the total nitrogen in percentage of dry weight has been observed in the successive leaves mainly due to simultaneous increase in total dry matter, in much greater proportion. Protein-nitrogen concentration varies directly with the total nitrogen, but while expressed as percentage of total nitrogen it increases in the successive leaves indicating increased rate of metabolism in the later leaves. Rice plants are characterised by low concentration of amino and amide nitrogen. On transplantation a rapid uptake of nitrogen is noticed in the increased nitrogen content in the mature leaves (7th and 8th). This is followed by an increase in protein, amino and amide nitrogen fractions and a vigorous vegetative growth in height and tiller. When the ears are just emerging, translocation of organic nitrogen to this rapidly developing region is indicated by decrease in protein-nitrogen and increase in soluble fractions, specially amides and amino acids in the mature leaves.

In conclusion, I take this opportunity to express my sincere thanks to Dr. S. M. Sircar, under whose care and guidance this investigation was carried out, to Mr. B. N. Ghosh, for his active co-operation, and to Dr. J. C. Sen Gupta, for valuable suggestions and criticism.

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STUDIES IN CROP PHYSIOLOGY

Fertiliser Effects upon Seed Quality, Photosynthesis, Respiration and Chlorophyll Content of Wheat Leaves during Two Successive Generations

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INTRODUCTION

THE present paper attempts to elucidate the responses of wheat plants to the conditions of nutrient supply with special reference to (i) the ontogenetic drifts in photosynthesis, respiration and chlorophyll content of leaves; (ii) the diagnostic effects, if any, of nitrogen, phosphoric acid and potash upon these plant processes; and (iii) the lasting or transitory nature of fertiliser effects on the above activities through two successive generations of the crop.

Mineral deficiency is known to induce subnormality in photosynthesis (Briggs, 1922). Nitrogen of all elements has little effect upon CO_2 intake (Gregory and Richards, 1929) though it increases leaf assimilating surface (Gregory, 1926). Its deficiency reduces respiration rate of barley leaves (Gregory and Sen, 1937) but increases assimilation of these leaves (Gregory and Baptiste, 1936), such increases in photosynthesis are usually associated with high sugar content, low respiration, low protein synthesis and low meristematic activity. Application of N on the other hand increases respiration (Hamner, 1936) provided an initial carbohydrate reserve is present; chlorophyll is also increased (Tam and Magistad, 1935), if other conditions of chlorophyll formation are available. Previous work from this laboratory (Singh, *et al.*, 1939) also indicates the utility of nitrogen in increasing photosynthesis. Association with nitrogen of P and K causes slackening in activity; the deleterious effect is less, if one of these ingredients is reduced. Presence of complementary factors greatly alters photosynthesis (Singh and Lal, 1940). Nitrogen also augments photosynthesis of sugarcane leaves throughout the life cycle; respiration is only increased during early stages (Singh, 1941).

Addition of phosphate is also known to increase assimilation rate (Gregory and Richards, 1929). Its importance is felt more during early stages when it invigorates growth and development (Brenchley, 1929). Phosphate supply increases respiration (Lyon, 1923, 1929) but reduces assimilation rate of sugarcane leaves (Singh, 1941). Respiration of these leaves on the contrary, is augmented only during later periods of the life-cycle.

In K deficient cultures respiration is super-normal while assimilation is subnormal (Gregory and Richards, 1929). Increase in assimilation takes place as the level of external potassium concentration is lowered (Richards, 1932). Potash is singly more useful than nitrogen in increasing photosynthetic activity of leaves (Singh, *et al.*, 1939). Assimilation and respiration rate of sugarcane leaves also increases during early periods in response to potash; during late season, assimilation however is lowered (Singh, 1941). Marked differences in chlorophyll content caused by potash have also been noted by Schertz (1929) and Maiwald (1923). It remains however, to be seen as to how far the application of nitrogen, phosphoric acid and potash affects these physiological characters in wheat at successive stages of the life-cycle. Relevant data collected in these directions are presented in the following pages.

Method and Material

The investigation was conducted on wheat (var. Pusa 52) grown in small size (11" × 9") pots, each filled with 10 kgm. of farm soil (sandy loam) and supplied with eight combinations of nitrogen, phosphoric acid and potash as indicated below :—

(i) No manure (C)
(ii) Nitrogen (N)
(iii) Phosphoric acid (P)
(iv) Potash (K)
(v) Nitrogen and phosphoric acid (NP)
(vi) Nitrogen and potash (NK)
(vii) Potash and phosphoric acid (PK)
(viii) Nitrogen, phosphoric acid and potash (NPK).

N, P and K were added at the rate of 24 gm. sulphate of ammonia, 6·6 gm. double superphoshpate, and 4·3 gm. sulphate of potash respectively, per ten pots; treatments were replicated three times. Six plants per pot were grown for the whole of the life-cycle in each of these cultures. Regular hoeing and watering were done to assure good growth.

Measurement of photosynthesis and respiration rates, and chlorophyll content were undertaken on second leaf collected from the top of the primary shoot only. Such leaves were selected at regular intervals of the life cycle from different series of cultures and were kept under laboratory conditions over night. Photosynthesis and respiration rate of such leaves were determined by continuous current method using baryta solution as an absorbent. Chlorophyll content of leaves was estimated on fresh material after Oltman's method*.

Seeds collected from different fertiliser cultures in the first year of the experiment were grown in the next season again in pots filled with farm soil. Each of the eight series of cultures was separately

* *Plant Physiol.*, 1932, 8, 321–26.

maintained. No fertilisers were applied in the second year, and plants were grown under basic level of soil nutrition. Leaves from all the eight cultures were again picked up during the life cycle and their photosynthesis, respiration and chlorophyll content estimated after the manner described above. Assimilation measurements were done under 0·25–0·3 per cent. carbon dioxide concentration, 31° C. temperature and light intensity of 1,500 W. from Phillips bulb maintained at a distance of 18 cm. from the chamber. Heat rays were cut off by a screen of running water interpoused between the bulb and chamber.

Total nitrogen content of grain during two years was also determined by Kjeldahl's method. Percentage of crude protein in these seeds was computed by multiplying total nitrogen values by 6·25.

Experimental Findings

A. *Photosynthetic drifts in relation to fertilisers during* 1937–38

During the wheat season (1937–38), the rates of photosynthesis of leaves under single fertiliser cultures (N, P and K) showed high values at two stages, one at 30 days and the second at 75 days, in the life-cycle. Relatively, nitrogen exhibited the highest rate of photosynthesis (Table I, Fig. 1) during the period of first maximum; all other cultures (P, K. and C) did not indicate marked differences amongst themselves but were inferior to cultures supplied with nitrogen alone. At the stage of second maximum, all cultures (N, P and K) were superior to control but individually they did not exhibit any marked differences amongst themselves.

In the two and three fertiliser cultures, the period of high photosynthetic activity was again noticed at two stages, namely 45 and 75 days, in the life-cycle. Relatively higher rates of photosynthesis were recorded at the latter stage when NPK treated plants showed maximum activity. In between these two periods of high activity there was located at 60 days, a period of low photosynthesis in all the cultures.

Statistical analysis of the data showed significantly higher rates of photosynthesis in N treated plants as compared with others. Differences between P and K and between NK and NPK were, on the other hand, not significant at all. Untreated plants were very low in their photosynthetic activity and were followed by PK treated ones. Main effect of N was positively significant; those of P and K were insignificant. Of all the interactions, N × K was only negatively significant.

B. *Respiratory drifts in relation to fertilisers during* 1937–38

Rate of respiration of leaves also fluctuated at different stages of the life-cycle under all the treatments. In general, respiration was high during early periods, low during 45–60 days and again high between 60–75 days under majority of the fertiliser cultures (Fig. 1). The overall age values indicate a significantly lower rate of respiration in K treated plants; in others, the increases or decreases were not significant at all. Untreated plants showed least respiration. All main effects and interactions were insignificant (Table I).

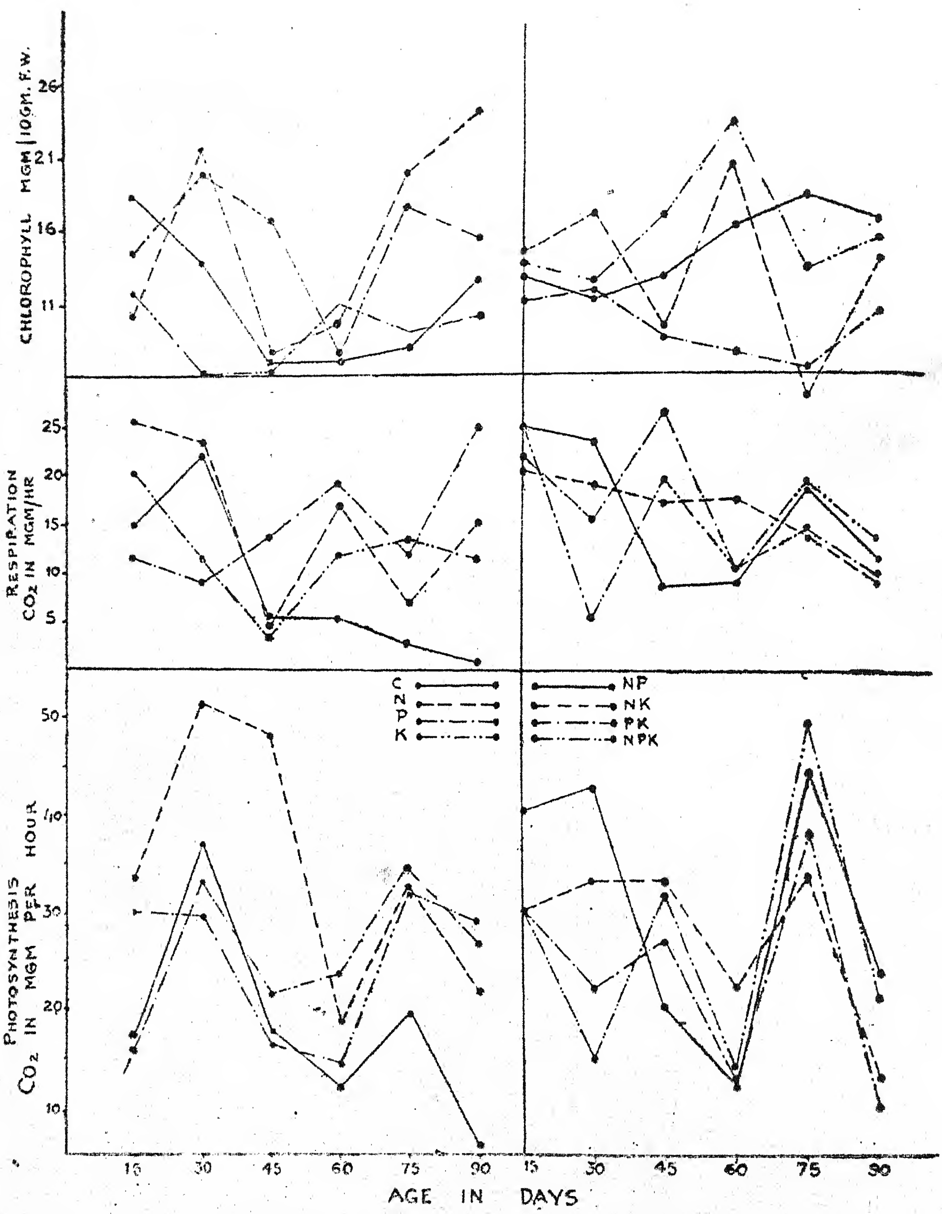

Fig. 1. Photosynthesis, respiration and chlorophyll content of wheat leaves under different fertilisers (1937–38).

TABLE I

Fertiliser effects upon real assimilation, respiration and chlorophyll content of wheat leaves during two successive seasons

Treatments	1937—38		1938—39	
	Mean	M. E. and Int. (Total)	Mean	M. E. and Int. (Total)
Photosynthesis				
C ..	18·2	..	59·35	..
N ..	34·4	+ 162·00**	76·06	+ 16·6
P ..	25·9	+ 6·48	46·80	− 67·0
K ..	25·3	· 36·00	56·10	− 135·8
NP ..	30·1	− 62·22	57·90	+ 10·8
NK ..	27·6	− 89·82*	40·10	− 55·8
PK ..	23·3	− 39·00	58·60	+ 178·4
NPK ..	26·9	+ 77·64	52·20	+ 55·4
C. D.—5% ..	± 7·7	..	±24·2	..
S. E. ..	..	± 44·8	..	± 92·9
Respiration				
C ..	8·75	..	25·10	..
N ..	15·20	+ 62·10	30·55	− 2·16
P ..	15·00	+ 62·34	28·45	+ 2·04
K ..	11·70	+ 33·66	19·75	− 37·36
NP ..	15·59	− 62·04	20·25	− 60·36
NK ..	15·60	− 22·50	18·97	− 0·36
PK ..	15·80	− 17·16	24·12	+ 76·72
NPK ..	15·30	+ 11·70	24·64	+ 69·84
C. D.—5% ..	± 7·5	..	± 19·73	..
S. E. ..	..	± 44·4	..	± 76·12
Chlorophyll				
C ..	11·1	..	22·95	..
N ..	15·5	+ 84·6*	24·82	− 13·16
P ..	15·3	+ 30·0	28·76	+ 8·64
K ..	9·2	+ 56·4	21·45	− 88·44**
NP ..	14·5	− 12·6	24·72	− 17·76
NK ..	13·0	+ 42·0	22·52	− 2·84
PK ..	8·9	− 3·8	18·93	− 37·04
NPK ..	15·6	+ 48·6	18·98	+ 19·56
C. D.—5% ..	± 5·2	..	± 6·22	..
S. E. ..	..	± 31·13	..	± 23·04

* Significant at 5%. ** Significant at 1%.

C. Chlorophyll content in relation to fertilisers during 1937–38

Chlorophyll content of leaves also fluctuated widely from one stage in the life cycle to another. In single fertiliser series high chlorophyll was recorded at 30 days, low at 60 days and again high at 75–90 days in the life-cycle. In the two and three fertiliser cultures, fairly high chlorophyll content was recorded at 60 days in case of NPK and NK cultures. Plants supplied with PK consistently showed a decline till 75 days and only exhibited a rise at 90 days (Fig. 1). All treated cultures except PK and K were higher in chlorophyll than the control. Chlorophyll content of N, P and NPK treated wheat was high ; differences between these treatments were not significant at all. Main effect of N was however only significant (Table I).

D. Effect of age on physiological drifts during 1938–39

The effect of age on physiological drifts during 1938–39 was more or less of a similar nature in all the series of cultures. Treatment with any nutrient in the previous life cycle brought about only slight variation in photosynthesis, respiration and chlorophyll content of leaves during the following season. Photosynthesis showed an increase from 30-60 days in seven out of eight cultures reaching a maximum at 60 days and subsequently showing a decline (Fig. 2). This fall towards the end of the life-cycle was characteristically noted in all cultures. Respiration also exhibited high values at 30 days in case of K, NP and NK cultures; in others high carbon dioxide output was recorded only at 60 days. This more or less coincided with the maximum obtained for photosynthesis. Decline in respiratory activity with age was also uniformly noted in all the cultures (Table I).

On chlorophyll the effect of age was slightly different from that of respiration or photosynthesis. Leaves continued to exhibit increasing chlorophyll content with advance in age till 120 days in the life-cycle.

TABLE II

Age effects upon photosynthesis, respiration and chlorophyll content of leaves (1938–39)

Age in days	mgm. CO_2/100 sq.cm.		Chlorophyll mgm./10 gm. f.w.
	Assimilation	Respiration	
30 ..	75·62	42·64	15·73
60 ..	106·10	39·88	21·94
90 ..	26·87	7·9	25·44
120 ..	15·92	7·56	28·46
Critical difference ..	± 17·22	± 14·11	± 11·65

The overall treatment values indicate the effect of age to be significant at almost all stages of growth in case of photosynthesis. In case

TABLE III

Protein content of seeds under different treatments during two successive generations

Treatments	Protein content		% Decrease
	1937—38	1838—39	
C ..	13·75	5·0	63·6
N ..	21·63	9·38	56·6
P ..	13·00	6·06	53·39
K ..	14·31	3·93	72·54
NP ..	14·56	7·18	50·63
NK ..	14·12	6·56	53·55
PK ..	13·00	4·37	66·39
NPK ..	14·56	7·50	48·50

TABLE IV

Average meteorological conditions at Benares during growing season (October–March)* 1937–38 *and* 1938–39

Meteorological factors	1937—38*	1938—39*
Mean dry bulb temp. 8 hrs. L.M.T. ..	64·08	63·8
,, wet ,, ,, ..	57·78	57·60
,, dry ,, 17 ,, ..	77·23	79·03
,, wet ,, ,, ,, ..	63·06	62·83
,, daily Max. Temp. ..	81·75	82·91
,, ,, Min. ,, ..	56·41	58·28
,, R. H. at 8 hrs. L.M.T. ..	67·83	68·0
,, ,, 17 I.S.T. ..	45·0	38·33
,, daily wind velocity M.P.H. ..	47·33	44·0

of respiration, significantly higher rates were recorded during early stages only. Age significantly increased chlorophyll content only beyond 60 days in the life-cycle (Table II).

E. Treatment effects on physiological drifts during 1938–39

Taking overall age values into consideration the rate of photosynthesis was found to vary from treatment to treatment (Table I). Least photosynthesis was recorded under NK treatment and highest under N; differences between these two were statistically significant. All other cultures did not differ significantly either from the values recorded for N or NK treated plants.

Respiration was highest under nitrogen and lowest in case of NK (Table I). Both these cultures did not differ significantly amongst themselves. Nitrogen, however, was not significantly superior to others.

* Average value calculated from the data kindly supplied by the Director-General of Observatories, Poona.

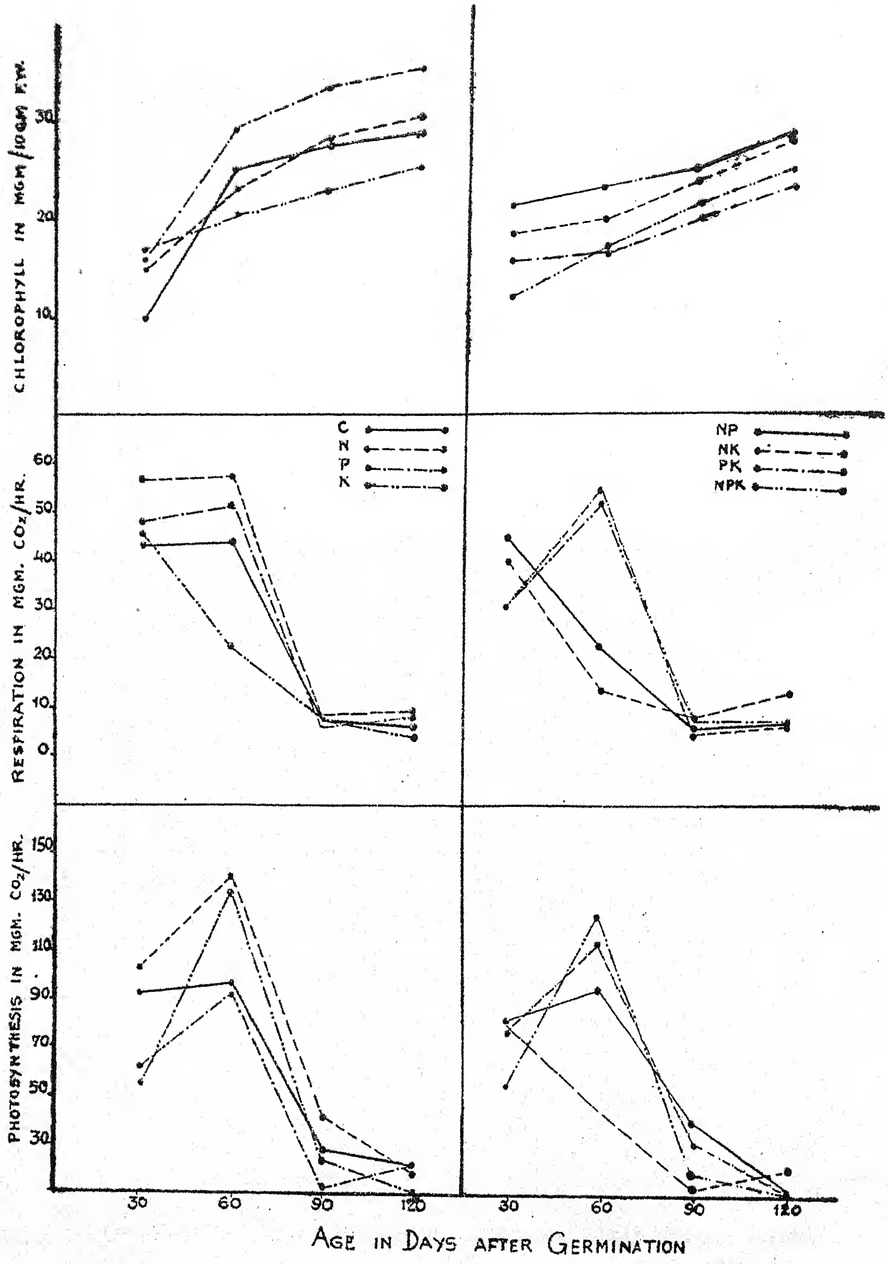

Fig. 2. Photosynthesis, respiration and chlorophyll content of leaves in different cultures (1938–39).

The effect of fertilisers on chlorophyll was slightly different. P treated plants were highest in chlorophyll followed by N. Differences between the two were statistically insignificant. NPK and PK treated plants showed the least chlorophyll content and were significantly inferior to only the P cultures in this regard.

All main effects and interactions were, however, insignificant in case of photosynthesis and respiration. On chlorophyll potash only exhibited significantly deleterious effects.

F. Protein content of grain during two generations 1937–38 *and* 1938–39

Protein content of grain during the first year of the experiment varied from a maximum in the N treated plants to a minimum in the P and PK treated plants. No marked differences amongst different treatments (except N) were discernible. In the second year of the investigation when the seeds collected from differently treated pots were sown under basic level of soil nutrition the protein content of the grain varied more characteristically. Nitrogen applied alone in the previous year showed the maximum protein content followed by NPK and NP cultures while K exhibited the least protein (Table III) in the second year of experiment.

Percentage decline in protein content in the second generation amounted to more than 50 per cent. in majority of the treatments. Full fertiliser (NPK) treatment showed the minimum decline in the second generation while seeds from K exhibited the maximum fall. The reductions were of the same order in case of N, P and NK treatments. Control and PK treated plants were midway between the K and N treated series.

Meteorological records during the growth period of wheat during the two successive seasons indicated more or less identical climatic conditions (Table IV). Relative fall in the protein value of the grain during the second season, therefore, gives indication to the view that better quality of seeds once induced as a result of fertiliser application cannot for all times be maintained in the next generation if the plants do not receive any nutrients during their development. The effect of nutrition appears to be of a transitory nature, affecting the metabolism of cells and not interfering to any marked degree with the genetic constitution of the seeds produced. If quality is to be maintained, each successive generation of plants need receiving adequate fertiliser dressing.

Discussion

Data recorded in the previous pages indicate, in general, the importance of age in inducing high or low photosynthetic activity. Depending upon the quantity of nutrients added, however, differences in magnitude of photosynthesis at majority of stages and in particular during periods of high activity were noted. The mean life-cycle values under a particular fertiliser ingredient indicate the importance of nitrogen in increasing the photosynthetic efficiency of leaves. This is in conformity with the results obtained earlier (Singh, 1941) where

it has been pointed out that in sugarcane, nitrogen increases assimilation rate throughout the life-cycle. Nitrogen thus in both the crops (wheat and sugarcane) has an augmentative effect upon this physiological process.

On respiration and chlorophyll content, as the main effects and interactions indicate, none of the ingredients, N, P and K, showed any significant response although the data in sugarcane (Singh, 1941) indicated the importance of nitrogen and potash in increasing photosynthesis and respiration both during early stages of growth. For obtaining best response from the point of view of photosynthetic activity of wheat leaves it appears, therefore, that its supply should be assured sufficiently early in the life-cycle long before the attainment of the first maximum at 30 days. From the point of view of these characters, P and K do not appear to be of so much importance in these soils.

No conclusive view could be advanced in the light of the above observations upon the role of N, P and K upon respiration and chlorophyll content of leaves although the recent researches of Gregory and his school (1926, 1929, 1936, 1937) point out the profound influence that N and K have upon the respiratory drifts in barley leaves. Significant reductions in respiration rate in N deficient cultures and significant increases in the same activity in K deficient series were recorded by Gregory and Sen (1937). The data further reveal that the effect of fertilisers is not necessarily of a lasting nature inasmuch as seeds raised under different fertilisers when sown under one nutritional condition in the subsequent season hardly, if ever, indicate differential photosynthetic activity at various stages in the life-cycle ; so were the effects in case of respiration. On chlorophyll deleterious effects were noticeable in plants raised from seeds of K series of cultures. Lower chlorophyll content in this series was also accompanied by greatest reduction in protein content of the grain in the second generation. These facts give evidence to the necessity of proper fertiliser rationing during successive cropping seasons if seeds of good quality (high protein content) are desired.

Summary

In the previous pages have been discussed the effect of N, P and K application upon ontogenetic drifts in photosynthesis, respiration and chlorophyll content of leaves during two successive seasons. The experiments were conducted in pots filled with farm soil (sandy loam) as the medium of growth.

Photosynthetic activity of leaves was significantly increased in response to N fertilisation. On respiration none of the fertilisers had any significant effect. On chlorophyll main effect of N was only significant.

Two periods of high photosynthetic activity were recorded, one during early stages (15–30 days) and the other during later periods (60–75 days). On chlorophyll the average effect of age was to increase chlorophyll content till 120 days. Significantly high photosynthetic

rates at majority of stages, high respiration rates during early periods and high chlorophyll content beyond 60 days were the characteristic responses of age upon these characters.

No significant differences in photosynthesis and respiration during the second generation in response to fertilisers applied during previous life-cycle were recorded. On chlorophyll seeds raised from K alone exhibited significant reductions during the second season.

Protein content of seed was decreased in the second generation in all cultures irrespective of whether the plants were raised from seeds produced under one or the other of the eight combinations of N, P and K.

Significance of these results has been discussed.

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SOME FACTORS AFFECTING THE GROWTH AND SURVIVAL OF *FUSARIUM VASINFECTUM* ATK., THE COTTON WILT PATHOGEN IN THE SOIL, WITH SPECIAL REFERENCE TO MICROBIOLOGICAL ANTAGONISM

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INTRODUCTION

NUMEROUS studies have been made on the growth of the fungus *Fusarium vasinfectum* Atk., as affected by various factors like temperature, pH, etc., in pure-culture, by a number of workers (Neal, 1927; Fikry, 1932; Kulkarni, 1934; Mitra and Kheswalla, 1935). The media used in these studies have mostly been synthetic agar media or in other cases synthetic liquid media, the growth of the fungus usually being measured in terms of the diameter of the colonies in the former case, and in terms of dry weight of fungal growth in the latter. While pure-culture studies have been useful in many ways, such studies have not taken full cognisance of Fawcett's (1930) well-known assertion that "nature does not work with pure cultures alone," but most frequently with a varied and diverse microfloral complex. Quite recently a vast amount of literature has accumulated on the subject of antagonism which emphasizes the importance of the microbiological factor of the soil, especially in relation to soil-borne diseases and their control.

On the one hand, experiments conducted in this laboratory to grow *Fusarium vasinfectum* in (i) ordinary unsterilised soil, (ii) the same soil (*a*) with addition of steamed rice (powder), (*b*) with addition of steamed rice (powder) and cane-sugar, and (*c*) with addition of Duggar's synthetic nutritive solution, resulted in failure, with *Mucor* sp., and other fungi predominating in all cases. On the other hand,

experiments in which attempts were made to grow the fungus in parallel sterilised treatments all succeeded, better growth being obtained when rice powder, cane-sugar and Duggar's solution were used as extra nutrients. It was, therefore, clear that nutritional deficiencies were not responsible for the failure of the fungus to grow in the unsterilised soil but that the inhibiting factors were indicative of antagonism by the soil microflora.

Further work was, therefore, necessary to explain the failure of the fungus to grow in the unsterilised soil. Accordingly, an investigation of the factors affecting the growth and survival of *Fusarium vasinfectum* in the soil, using the direct microscopic method of Cholodny (1930), was taken up and forms the subject of the present communication.

Experimental

Technique.—A modified Cholodny slide technique was used throughout the course of this investigation. The technique consisted in burying thin films of the pathogen, *i.e.*, *Fusarium vasinfectum* Atk., grown on sterile slides into the soil, and taking them out at intervals for examination. The detailed experimental procedure was as follows: Clean microscope slides preserved in absolute alcohol were used for the purpose. A spore suspension was prepared from a culture of the fungus *Fusarium vasinfectum* grown in Duggar's solution for ten days (incubation temperature 29°–32° C). The spore suspension was added at the rate of 1 c.c. for 10 c.c. of a modified Horne and Mitter's medium, maintained at about 42° C. The spore suspension was mixed well with the medium, and the Cholodny's slides were coated on a limited area of the slide only with this spore-suspension-in-agar and incubated at room temperature in sterile moist chambers in the form of petri dishes. The slides were later on taken out after definite periods of incubation and then buried in soils placed in cylindrical container jars of size 4″ × 3″ which had been previously autoclaved at 15 lbs. pressure for 20 minutes. In the case of sterilised treatments the containers were sterilised along with the soil by autoclaving at 20 lbs. for 2 hrs. The moisture percentage of the soil in all cases was adjusted to 50 by addition of the calculated amount of sterile distilled water. The process of burying the slides and their removal was in essentials that of Conn (1932). This was done as follows: the slides were buried vertically (with their longer edges parallel to the sides of the container) in trenches dug in the soil. Some soil (adjusted to 50% moisture, sterilised or unsterilised and with or without amendments according to the treatment) was then loosely packed all around the slides. The whole operation was done under aseptic conditions. The slides so buried were incubated in the soil for definite periods before they were taken out for examination. In removing the slides, the entire core of soil with the buried slides was first smartly tapped out from the container and then the slides were pulled away from each face of soil in turn, taking care to see that the thin film of micro-organisms on the slide was left intact. The staining procedure of Jensen (1934) was found to be most suitable and has been used throughout the course of this investigation. Jensen's staining method was as

follows: "(1) After air-drying and removal of sand-grains, the slide is passed through a Bunsen flame to fix the micro-organisms.—(2) Staining 2–3 minutes with Crystal-violet-ammoniumoxalate-solution (Gram-Hucker).—After washing treatment for 1–2 minutes with Lugol's iodine.—(3) Washing, drying, and differentiation 4–5 minutes with absolute alcohol which is renewed 3–4 times.—(4) Drying and counter-staining 10–12 minutes on water-bath at 60–70° C. with Rose bengale solution after Conn (1932)" (Jensen, 1934, p. 202). Every region of the stained preparations was carefully explored under the microscope, and representative formations were photomicrographed. Some of the photomicrographs are reproduced in Plate V.

Two soils were used*:

(1) A sandy compost soil prepared by mixing sand, red earth and dung manure in the proportion of 2 : 1 : 2. Saturation capacity 33·9; pH 6·5 approximately.

(2) A sticky black cotton soil from Udamalpet (Coimbatore Dt., Madras Presidency). Saturation capacity 72·3; pH 8 approximately.

Two different strains of *Fusarium vasinfectum* pathogenic to cotton were employed during this investigation: (1) a culture of *Fusarium vasinfectum* pathogenic to cotton kindly sent by Mr. K. M. Thomas, Government Mycologist, Coimbatore. This strain has undergone continued subculturing through several generations; (2) a strain of *Fusarium vasinfectum* pathogenic to cotton recently isolated by the author in this laboratory from wilted cotton plants from a typically *Fusarium*-wilt-infected field at Udamalpet. The strain resembled Mr. Thomas's type culture in every way, both morphologically and physiologically. The demonstration of the pathogenicity of the isolate to cotton, coupled with the historical interest which attaches to Udamalpet cotton fields as being typically infested with *Fusarium vasinfectum*-wilt for a period of years tends the author to consider the isolate in question to be a strain of *Fusarium vasinfectum*, although more data are needed to confirm this.

Experiment I.—300 gm. each of air-dry sieved compost soil were taken in 6 containers. The 6 containers consisted of the following treatments, with 3 jars for each treatment:

(1) Soil unsterilised,

(2) Soil sterilised.

The Cholodny's slides were incubated in the moist chambers for 3 days before burial. 2 slides were buried in each jar. The 2 slides from one jar of each treatment were taken out after incubation for 7, 14 and 28 days. The results have been incorporated in Table I.

Table I clearly brings out the effect of microbial antagonism on *Fusarium vasinfectum* mycelium buried in the unsterilised soil.

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* Detailed work on the mechanical and chemical analyses of these soils is in progress, and the relation of the same to the behaviour of *Fusarium vasinfectum* will form the subject of a subsequent communication.

TABLE I

Results of experiment I showing behaviour of Fusarium vasinfectum *in sterilised and unsterilised soil after* 7, 14 and 28 *days*

No.	Treatments	Attacked, decomposed, or healthy	Vegetative mycelium			Conidia and Chlamydospores	Remarks
			Incubation period				
			7 days	14 days	28 days		
1	Soil unsterilised	Attacked and decomposed	Attacked, decomposition gone half-way through	Attacked, decomposition almost complete	Absent, decomposition complete	No conidia or chlamydospores were seen (presumably because none were formed either before or after burial of the slides)	Besides bacteria, 3 or 4 other filamentous fungi could be seen
2	Soil sterilised	Healthy, not attacked or decomposed	Abundant	Abundant	Abundant	Present; increased in number with the period of incubation of the slide in the soil	Chlamydospores intercalary or terminal, thick-walled without ornamentations

Progressive decomposition of the mycelium was seen in the weekly observations until ultimately no trace of hyphæ could be recognized. 28 days' incubation represented complete decomposition of all mycelia of *Fusarium vasinfectum* in the unsterilised soil. In the sterilised soil none of these changes could be noticed. Indeed, the fungus produced conidia and chlamydospores prolifically due to the absence of competition for the available food material by the soil-inhabiting micro-organisms and also due to the survival of the mycelium without the decomposing effect of the soil organisms so clearly seen in the unsterilised soil.

Experiment II.—Both the soils mentioned above were used in this experiment. 16 container jars were used, with 2 slides in each jar. The slides were incubated in the soil for 4 days in the case of unsterilised treatments and for 15 days in the case of sterilised treatments. A summary of the various treatments is given below :

Series	*Sub-series*	*Treatments*
I. Compost Soil	(*a*) Unsterilised	1. Untreated (control)
		2. + 0·3% $Ca(OH)_2$
		3. + Calcium phosphate (monobasic) 1·0%
		4. + stable manure 3·0%
	(*b*) Sterilised	5. Untreated (control)
		6. + 0·3% $Ca(OH)_2$
		7. + Calcium phosphate (monobasic) 1·0%
		8. + stable manure 3·0%
II. Udamalpet Soil	(*a*) Unsterilised	9. Untreated (control)
		10. + 0·3% $Ca(OH)_2$
		11. + Calcium phosphate (monobasic) 1 0%
		12. + stable manure 3·0%
	(*b*) Sterilised	13. Untreated (control)
		14. + 0·3% $Ca(OH)_2$
		15. + Calcium phosphate (monobasic) 1·0%
		16. + stable manure 3·0%

The results obtained are shown in Table II.

Table II presents the following results : (*a*) in the unsterilised soils of both types (*i.e.*, Compost Soil and Udamalpet Soil) in all the different treatments, *F. vasinfectum* mycelium was attacked and decomposed by other soil organisms, more rapidly where stable manure had been added. Calcium phosphate (monobasic) retarded to some extent the rate of decomposition of the mycelia ; (*b*) in the sterilised soil, the growth of *F. vasinfectum* was quite healthy, and was considerably accelerated with profuse spore-forming tendencies when stable manure or phosphate was added.

TABLE II

Results of experiment II showing the effect of various soil amendments on the behaviour of Fusarium vasinfectum *in sterilised and unsterilised soil*

Series	Sub-series	Treatments	Whether attacked and decomposed or healthy	Stage of decomposition *	Vegetative mycelium	Conidia	Chlamydospores	Growth on soil surface and sides of container	Growth on slide surface	Remarks
I Compost Soil	*a.* Unsterilised	1. Untreated	Attacked	++	Attacked	None could be seen, evidently decomposed	Present, but attacked by bacteria	None	None	
		2. +0·3% Ca $(OH)_2$	do	+++	do	Surrounded and attacked by bacteria	Attacked by bacteria and fungi	do	do	Various stages of decomposition of conidia and chlamydospores by bacteria and of chlamydospores by certain unidentified filamentous fungus. Final digestion of the chlamydospores by the filamentous fungus
		3. Calcium monobasic phosphate 1·0%	do	+	do	Numerous	Numerous	do	do	Decomposition slower than in other treatments of the series

		4. +3·0% stable manure	do	++++	De-compos completely	None, evidently de-composed	Fairly numerous, surrounded and attack-ed by bacteria	do	do	Decomposition fastest among treatments of series. Slides especially characterised by the presence of certain mycelial forms certain rounded unicellular forms. Micro-flora more varied and dense than in other treatments of the series
	b. Steri-lised	5. Untreated	Healthy, not attacked or decomposed	..	Abundant	Present many	Present many	None on soil suface, fine meshes of mycelia on sides of vessel	Fairly good growth	
		6. +0·3% $Ca(OH)_2$	do		do	Present	Present	Very little	Not much	
		7. +Calcium phosphate (mono-basic) 1·0%	do		do	Present, numerous	Present, numerous	Better growth on soil surface and sides of vessel than in (5) or (6)	do	Conidia more numerous than chlamydospores
		8. 3·0% stable manure	do		do	do	do	Maximum fluffy white growth on soil surface, mycelium had penetrated to bottom of vessel	Least fluffy growth	Conidia and chlamydospores more numerous than in "7"

TABLE II—(*Contd.*)

Series	Sub-series	Treatments	Whether attacked and decomposed or healthy	Stage of decomposition*	Vegetative mycelium	Conidia	Chlamydospores	Growth on soil surface and sides of container	Growth on slide surface	Remarks
II Udamalpet Soil	*a.* Unsterilised	9. Untreated	Attacked and decomposed	++	Attacked	Present, surrounded and attacked by bacteria	Present, surrounded and attacked by bacteria	None	None	
		10. +0·3% Ca $(OH)_2$	do	++	do	None, evidently decomposed	Present	do	do	
		11. +Calcium monobasic phosphate 1·0%	do	+	Attacked, but much of mycelium intact	Present, numerous	Present, numerous	do	do	Extent of decomposition much less than in (9) or (10)
		12. +3% stable manure	do	++++	Attacked and decomposed	None, already decomposed	Present	do	do	Maximum decomposition
	b. Sterilised	13. Untreated	Healthy, not attacked or decomposed	..	Abundant	Present, numerous	Present, numerous	Mycelial ramifications on sides of vessel only, no growth on surface	More fluffy than when burried in soil	

		14. +0·3% Ca $(OH)_2$	Healthy, not attacked	..	do	Present	Present	None	Less growth than in (13) or (16) below	
		15. +Calcium monobasic phosphate 1·0%	do	..	do	Numerous	Numerous	Mycelial ramifications on sides of vessel only, no growth on soil surface	Same as in (14)	
		16. +3·0% stable manure	do	..	do	do	do	do	Some fluffy growth	Chlamydospores more numerous than in (13)

* Stages of decomposition :—
+ Decomposition started.
++ Decomposition gone half way through ; undecomposed filaments still surrounded by bacteria.
+++ Decomposition almost complete.
++++ Decomposition complete, no trace of *Fusarium* mycelium.

DISCUSSION

Microbiological antagonism as an important factor affecting the pathogenicity of various fungi is now well recognized. Excellent reviews on the subject have been published by Garrett (1934, 1939, 1944); Garrard and Lochhead (1938); Porter and Carter (1938); D'aeth (1939); Weindling (1938); Waksman (1941), and many others. With the realization of the importance of the biotic factor of the soil in relation to the incidence of soil-borne diseases and their control, the explanation for certain very old agricultural practices became quite obvious. The principle underlying all such practices consisted mostly in enhancing the general microbiological activity of the soil by cultural practices like manuring, etc. Much useful work along these lines was carried out by many investigators during the past 20 years all of which points undoubtedly to the fact that in the case of soil-borne diseases, disease incidence due to certain soil-borne pathogens is inversely proportional to the antagonistic micro-floral content of the soil. Manuring was one of the methods by which such increased microbial activity was achieved for the control of many soil-borne diseases. It has been established that the role manuring plays in the control of these diseases is primarily in its relation to increased microbial numbers, although it has not been proved that the role of manuring in plant disease control is not related to increased host resistance.

It is evident from the present study that the microbiological factor of the soil is equally important from the point of view of eliminating dangerous soil-borne pathogens during their saprophytic phase. For instance it has been found during this investigation that the saprophytic activity of *Fusarium vasinfectum* Atk., is very limited in the bare soil. In fact the fungus makes no spread at all in the soil. It is, on the other hand, parasitized upon by antagonistic bacteria until finally it is completely decomposed. Thus, it is found that the life of *Fusarium vasinfectum* in the soil is similar to that of *Ophiobolus graminis* (Garrett, 1936) in that it alternates between a parasitic ascendant phase in the presence of the host and a saprophytic descendant phase in the absence of the host. Regarding the latter phase of the fungus in the soil, on the basis of the data presented in this paper, *Fusarium vasinfectum*, the fungus causing Cotton Wilt, is provisionally placed in Garrett's (1944) class of fungi making no extensive spread through the soil.

It is considered that the deterioration and quick disappearance of *Fusarium vasinfectum* in unsterilised soil, far from being a case of the chemical, physical or even nutritional unsuitability of the soil, is, on the other hand, similar to that of *Ophiobolus graminis* (Sanford and Broadfoot, 1931), and is attributable to the rapid elimination of the pathogen from the soil due to the operation of the microbiological factor.

It has been shown further that dormant stages of *Fusarium vasinfectum*, *e.g.*, conidia and chlamydospores, can also be parasitized upon by antagonistic micro-organisms, both fungi and bacteria. This points to the possibility of biological control of Cotton Wilt by elimination of the dormant resting stages of the causal fungus in the fallow soil.

As regards the relative persistence of the mycelial and dormant stages of *Fusarium vasinfectum* in the soil, it has been shown that the chlamydospores persist for a longer time in the soil than the vegetative mycelium of the fungus or the conidia. In some treatments, *viz.*, I (*a*) 4 and II (*a*) 12 (see Table II), even though no trace of the mycelium or the conidia could be seen, chlamydospores were still present. This indicates that chlamydospores are more resistant to decomposition than the vegetative mycelium or the conidia.

The response of *Fusarium vasinfectum* in the sterilised soil to both manure and phosphate was somewhat similar: manuring accelerated the growth of the fungus, whereas phosphate was found to enhance the production of conidia and chlamydospores. However, it was found that in the unsterilised soil addition of manure accelerated decomposition, whereas phosphate retarded it. The retardation of decomposition of the *Fusarium* mycelium in the phosphate treatment was, therefore, a result primarily of the direct effect of the phosphate on the accelerating effect it had on the growth of the pathogen and presumably not on the general microflora. The acceleration of decomposition obtained with addition of manure was due to the increase in the activity of the soil organisms already present in the soil as well as the further increase in the activity produced by the addition of a complex flora contained in the manure.

SUMMARY

A study of some factors especially microbial antagonism on the growth and survival of the cotton wilt fungus, *Fusarium vasinfectum* Atk., has been made.

In the unsterilised soils the introduced pathogen was in all cases attacked and decomposed by the antagonistic soil microflora, especially bacteria.

Decomposition in all cases was usually found to have been completed in 1–4 weeks, varying according to conditions.

In the sterilised soil in all cases the introduced pathogen showed healthy growth and was characterised by the production of numerous conidia, mostly micro-, and also large number of intercalary and terminal chlamydospores.

The effect of certain soil amendments on the antagonism of microorganisms to *Fusarium vasinfectum* was studied. While 0·3% calcium hydroxide did not have any appreciable effect, 3% manure accelerated the decomposition of the *Fusarium* mycelium by the antagonistic microflora, and 1·0% monobasic phosphate of calcium retarded decomposition to some extent.

The effect of the same treatments on *Fusarium vasinfectum* in sterilised soil was also studied. It was found that 3·0% manure increased the vegetative activity of the fungus to a great extent and 1·0% calcium monobasic phosphate enhanced the production of chlamydospores and conidia by *Fusarium vasinfectum*. Calcium hydroxide was not found to have any appreciable effect on the vegetative or reproductive activity of the introduced pathogen.

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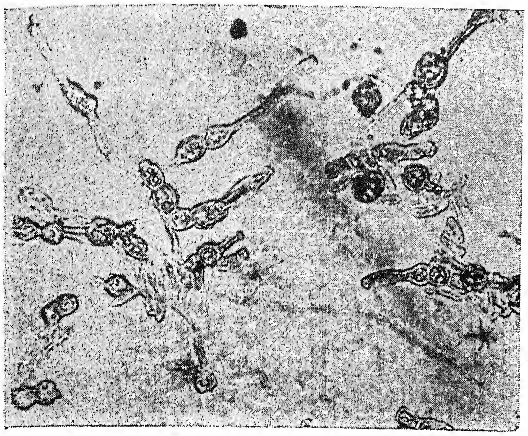

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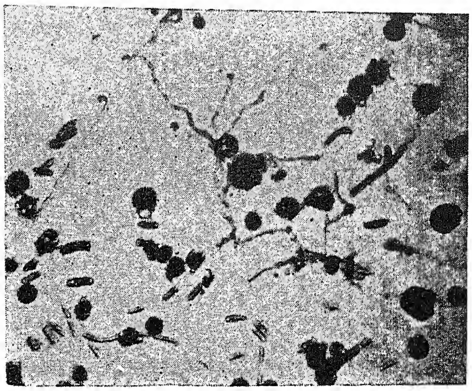

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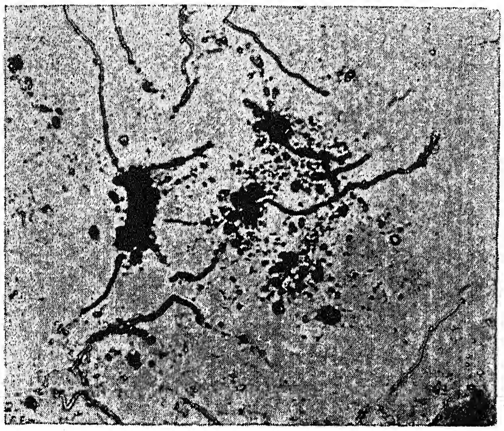

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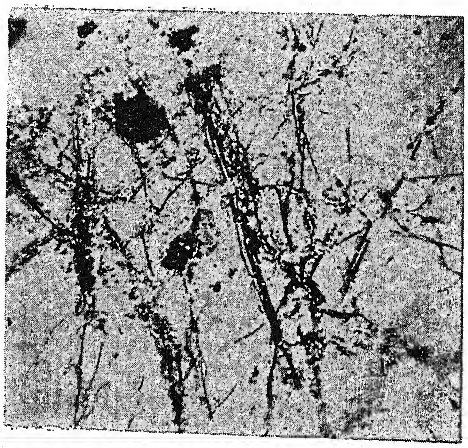

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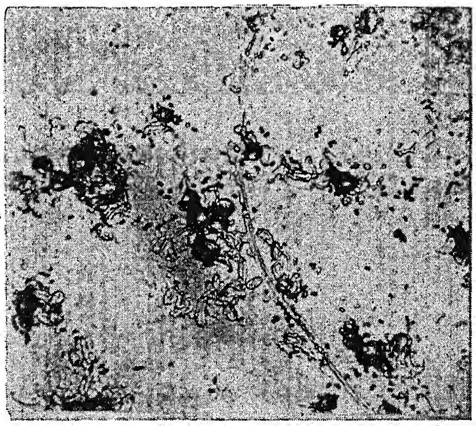

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C. V. SUBRAMANIAN—

SOME FACTORS AFFECTING THE GROWTH AND SURVIVAL OF FUSARIUM VASINFECTUM *ATK., THE COTTON WILT PATHOGEN IN THE SOIL, WITH SPECIAL REFERENCE TO MICROBIOLOGICAL ANTAGONISM*

EXPLANATION OF THE PLATE

Figs. 1 & 2. Behaviour of *Fusarium vasinfectum* in sterilised soil. Note unattacked healthy mycelium with many conidia and chlamydospores. Fig. 1 from Expt. II, treatment 16 ; Fig. 2 from Expt. I, treatment 2. ×400.

Figs. 3–6. Behaviour of the fungus in unsterilised soil.

Figs. 3–5. Successive stages in the decomposition of the *F. vasinfectum* mycelium by antagonistic bacteria.

Fig. 3. Initial stage of decomposition. From Expt. I, treatment 1. ×336.

Fig. 4. Intermediate stage of decomposition. From Expt. II, treatment 10. ×104.

Fig. 5. Final stage of decomposition. Also from Expt. II, treatment 10. Arrow points to vacant space originally occupied by the *Fusarium* mycelia. Note the dense bacterial growth surrounding the vacant space. ×104.

Fig. 6. Conidia and chlamydospores of *F. vasinfectum* surrounded by bacteria. From Expt. II, treatment 2. ×344.

A NOTE ON THE INFLORESCENCE OF *RICINUS COMMUNIS* LINN.

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Though *Ricinus communis* Linn. has been generally recognised to be monœcious, there has been some confusion as to the position of the male and female flowers on the main axis of the inflorescence. In some standard works, such as *Genera Plantarum* by Bentham and Hooker and the *Flora of British India* by Hooker, the female flowers are described to be arising at the bottom and the male flowers towards the top of the inflorescence, whereas Jussieu in his *Genera Plantarum* mentions that the male flowers are found towards the base and the females towards the top. These, in addition to the note in *Science and Culture* of April 1945, made us examine and study thoroughly the inflorescence of *Ricinus communis* from plants cultivated and growing wild as escapes at Coimbatore.

The inflorescence is an erect terminal branched raceme of cymes with staminate flowers at the lower portion of the flowering axis and the pistillate flowers towards the top. The lower branches of the racemes generally bear male flowers, though sometimes they have some female flowers towards the top. There are also rare cases where these two types of flowers are indiscriminately mixed and borne on the main axis of the inflorescence. W. B. Joshi (*Poona Agric. Coll. Mag.*, 1926, **18**, 20–22) records occasional cases of the "existence of diœcious plants" and plants with hermaphrodite flowers.

As early as 1768, in a drawing of *Ricinus speciosus* Burm., a synonym of *Ricinus communis* Linn. by Burmanni in *Flora Indica*, one pistillate flower is shown below with a number of male flowers above in the inflorescence. But the figures in Rheede's *Hortus Malabaricus* and *Rumphius Amboinense*, though not quite representative and true as the drawing in Curtis' *Botanical Magazine*, clearly bring out the inferior position of the male flowers and the superior position of the females on the inflorescence. In 1877, Kurz in his *Flora of British Burma* describes *Ricinus* as having female flowers in the lower part of the flowering axis. This mistake appears to have crept in Bentham and Hooker's *Genera Plantarum* of 1880 and has been repeated in several later publications. Prain in Thiselton Dyer's *Flora of Tropical Africa* and *Flora Capensis* follows Bentham and Hooker for the generic description of *Ricinus* ; but for *Ricinus communis* Linn., he rightly describes "the males below and females higher up". This mistake is also seen in the floral descriptions in the following publications, and requires the necessary corrections : (1) *The Botany of Bihar and Orissa* and (2) *Forest Flora of Chota Nagpur* by Haines. (3) *Flo a of Aden, Rec. Bot. Surv. Ind.* (4) *Flora of Madras* by Gamble. (5) *Indian Medicinal Plants* by Kiritikar and Basu. (6) *Cyclopedia of American Horticulture* by Bailey.

PALMOXYLON SCLERODERMUM SAHNI FROM THE EOCENE BEDS OF NAWARGAON, WARDHA DISTRICT, C.P.

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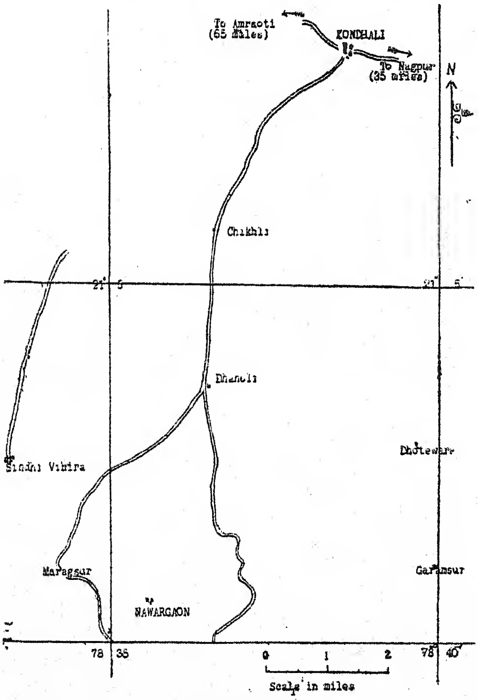
Introduction

A few years ago the author came across a petrified palm stump at the Central Museum, Nagpur. This stump had been collected by Mr. K. P. Sagreiya, I.F.S., in the forest area of Nawargaon (Lat. 21° 1′, Long. 78° 35′), Wardha district, C.P. (Text-fig. 1), in the year 1934 along with another palm stump and several fragments of petrified dicotyledonous woods. The entire collection was presented by Mr. Sagreiya to the museum. Suspecting this specimen to be a new



Text-Fig. 1

species of *Palmoxylon*, the author borrowed it through the kindness of the Curator for investigation. During the course of study the author compared it with the numerous species of petrified palms in the collection of Professor B. Sahni, F.R.S., which includes at least 45 new species of Indian Palmoxyla. It was discovered that the present species was already represented in that collection and had been named by Professor Sahni as *Palmoxylon sclerodermum* sp. nov. (Sahni, 1943). As the Nagpur specimen is more complete than the type specimen, the author on the advice of Professor Sahni undertook the re-investigation of the species based on the present specimen, in which the entire girth of the stem is preserved, with the roots in organic connection.

I am very much indebted to Professor Sahni who very kindly placed at my disposal his entire collection of palms for comparison and also his MS account of the different species. I may also take this opportunity of expressing my heartfelt thanks to my Professor for his kind guidance, valuable suggestions and criticism during the progress of this work.

The fact that fossil plants have been found in the region of Nawargaon has been recorded by Haines (1916, p. 5) and later by Sagreiya (1936, p. 2), but so far as I am aware no account of any petrified plants from this locality has yet been published. The fossils occur within an area of about four square miles and are best exposed along the slopes of a valley to the east of a cultivated field in Maragsur. They are embedded in lateritic morrum and can be easily excavated. Sometimes they lie partially or entirely exposed. Like most of the other beds in the Nagpur-Wardha region, these beds may also in all probability be referred to the Base of the Deccan Intertrappean Series, the age of which is now believed to be Eocene (Sahni, 1934).

Pieces of fossil wood also occur in the adjoining cultivated fields and in the region of Nawargaon forest village in the Hingni range.

DESCRIPTION

This solitary specimen is a brown coloured stump 1′–4″ long and 1′ in diameter at the base, narrowing to 8″ at the top (Photo. 1). Numerous roots are present at the base in organic connection forming a thick mantle round the stem (Photo. 15); their preservation is as good as that of the main stem. In the upper part of the stem the sheath of roots is replaced by a cortical zone about 3 cm. thick which surrounds the whole stem. It is possible that part of this cortical zone is really formed by the decurrent bases of leaves, but no persistent leaf-bases can be distinguished in the fossil.

Before proceeding with the description of the specimen, it may be advisable to say a few words about the descriptive terms used in the present paper. I have found it convenient to follow in the main the descriptive terminology used by Professor Sahni in his manuscript on the Indian petrified palms which I have consulted, and also in his account of the type specimen of the present species (Sahni, 1943).

Inwards the cortex, three zones may be distinguished in the stem: the dermal, subdermal and central (Photo. 5, D, S.d., N.). This

division into three zones is based on the following scheme adopted by Prof. Sahni :—

Bundle distribution and form of sclerenchyma	*Zone*	*Orientation of fibrovascular bundles*
Bundles crowded, *sclerenchyma* deformed by contact	Dermal	Usually normal
Bundles not crowded ; *sclerenchyma* retains its normal form	Subdermal	
	Central	Irregular

Similarly, the term *f/v* has been used to indicate the ratio between the cross-section area occupied by the sclerenchyma and by the vascular part of a fibrovascular bundle. I have also adopted the descriptive terms the dorsal and the ventral *sclerenchyma*, median sinus, auricular sinus, auricular lobes, etc., for the parts of the fibrovascular bundle.

The *cortex* is about 3 cm. in width (Photo. 2, C.).

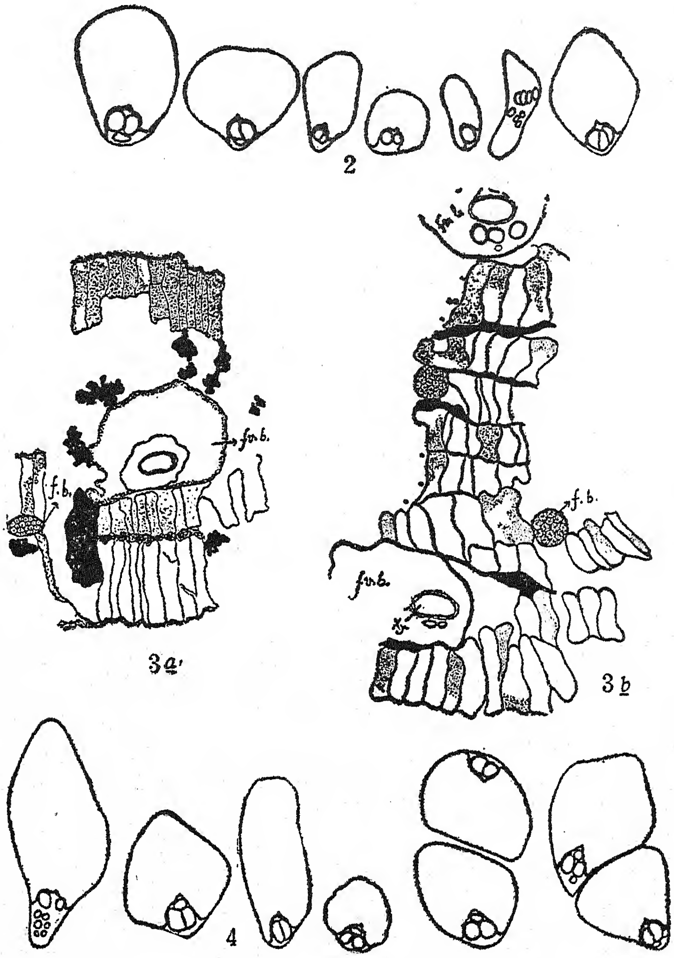
The fibrovascular bundles in this region as seen in cross-section are of varying form and size (Photo. 3, Text-fig. 2). Their average diameter across the *sclerenchyma* is ·35 mm. As a rule they are oval in shape, with a pointed end. The median sinus is cordate and xylem usually contains 3 to 4 vessels. The *f/v* ratio varies from 4/1 to 6/1. The *fibrous bundles* are scattered in the ground tissue and are usually of even size. A single bundle may on an average be made up of 12 to 15 fibres. Stegmata are present both on the fibrous and fibrovascular bundles.

The lacunar ground tissue is made up of parenchymatous cells which are light-brown coloured and mostly radially elongated and rectangular. They are usually arranged parallel to each other and often occur in layers (Photo. 3, Text-fig. 3).

The *dermal region* is about 2·5 cm. thick. The fibrovascular bundles, on an average 105 per $cm.^2$ and all normally orientated, are usually elliptic and as a rule larger than those in the cortex.

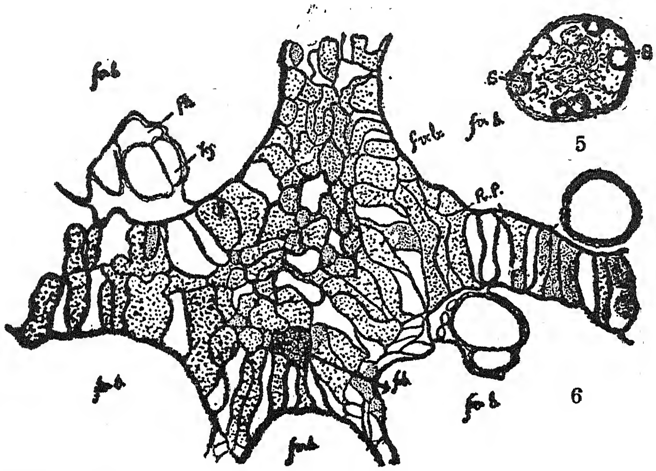
These bundles are again of varying form and size (Text-fig. 4). The smaller bundles being about ·4 mm. in diameter, the larger ones about twice as thick. These bundles are usually pressed against each other and show one or more flat sides. The auricular lobes are mostly rounded. In the xylem there is usually a single large median vessel and the *f/v* ratio varies from 9/1 to 18/1. The phloem (always very badly preserved) lies deep in the angles of cordate sinus. The fibrous bundles occur only here and there and are very much like those of the leaf-base region.

Stegmata are constantly present on the fibrous bundles (Text-fig. 5) and also on the fibrovascular bundles. The ground tissue is lacunar and composed of thin walled isodiamatric cells. It occurs in the form of tiny patches between the fibrovascular bundles which are very compact and at places where the bundles are very close to each other it may be only a single cell in thickness (Photo. 4).



Text-Figs. 2–4. Fig. 2. Some fibrovascular bundles from the cortical zone. × 50. Figs. 3 *a* and *b*. Two areas from the cortex showing radially elongated cells; *f.b.*, fibrous bundle; *fv.b.*, fibrovascular bundle; *Xy*, xylem. × 102. Fig. 4. Some fibrovascular bundles from the dermal zone. × 50.

A few leaf-trace bundles also occur in this region. They are distributed radially at great intervals throughout the zone and being cut obliquely appear radially stretched (Photo. 4, lt.). The dorsal *sclerenchyma* forms the major portion in these bundles but the xylem too is quite prominent. The vascular part comprises a number of vessels of medium size and the tongue-like process forms well-defined acute angled auricular sinuses with the auricular lobes. There also occurs a patch of ventral *sclerenchyma* at the extremity of this tongue-like process. The parenchymatous cells present over the projecting process are usually radially stretched.



Text-Figs. 5–6. Fig. 5. A fibrous bundle as seen in cross-section from the dermal zone showing stegmata (S) round it. × 205. Fig. 6. A patch of ground tissue from the subdermal zone as seen in transverse section. *fv.b.*, fibrovascular bundle; *Xy.*, xylem; *Ph.*, Phloem; *f.b.*, fibrous bundle. × 102.

The *subdermal zone* is nearly 2·5 cm. in width. The fibrovascular bundles (about 75 per cm.^{2}) are usually quite separate from each other and thus retain their normal form (Photo. 6) so that the form and structure of the bundles can be satisfactorily studied. They are mostly normally orientated and their average diameter as seen in cross-section is 1 mm. Their general outline is circular or slightly elliptic. The dorsal margin of the sclerenchyma is quite round and its base is cordate. Tabular parenchyma is often present in one or two layers (Photo. 10, T.). Auricular sinuses are quite insignificant as the auricular lobes merge insensibly into the sides of the xylem. Median sinus is quite well marked in most of the bundles. *Phloem* which is wedged in this sinus is often very poorly preserved. *Xylem* is usually 3 or 4 vessels, the larger two occurring ventrally and the other smaller ones placed internally to them (Photo. 6). Pitting of the metaxylem vessels is either scalariform or, more commonly, reticulate (Photo. 14, R.). The end walls of the vessels are very oblique and have scalariform thickening with wide spaces between the bars (Photo. 12, W.). *Fibrous bundles* occur sporadically in the ground tissue, a single bundle being usually made of 12–18 fibres. *Stegmata* are present both on the fibrous and the fibrovascular bundles and are best seen in longitudinal sections. Wherever the *sclerenchyma* is cut radially, the stegmata appear in two longitudinal rows along the margins (Photo. 11, S.) but if it is cut tangentially, they are seen to occur in several rows (Photo. 13, S.).

The *ground tissue* (Text-fig. 6) which here occupies an area comparatively larger than in the dermal region, is lacunar and made up of compact, rather isodiametric, small, thin-walled cells which appear slightly lobed in transverse section (Photo. 9, Text-fig. 6). At the

periphery of some ground tissue patches there also occur palisade-like rows of thin-walled cells (Photo. 7, R., Text-fig. 6, R.). Idioblasts occur here and there in the ground tissue.

As in the dermal zone, the radially stretched *leaf-traces* are present here too.

Central zone.—This has a radius of nearly 2·5 cm. and is characterised by irregular orientation (Photo. 8) of the fibrovascular bundles. At first sight these bundles look very much like those in the subdermal zone both in their form and distribution, but on closer examination they appear comparatively sparser, being 65 to 70 per cm^2. and show a more rounded dorsal *sclerenchyma* with its base definitely cordate (Photo. 10). The fibrovascular ratio is nearly the same as in the subdermal region, being about 23/1 and in other details too, the bundles of this region resemble those of the subdermal. Tabular parenchyma is also present (Photo. 10, T.). The fibrous bundles occur sporadically. They are made up of about 10–12 fibres, each about ·02 mm. in cross-section. Being badly preserved these bundles often get mixed up with the parenchymatous cells of the ground tissue (Photo. 9, F.). This tissue occupies just a little more area than in the subdermal region. Its cells again are mostly isodiametric, parenchymatous and lobed ; some of them appear to be thick walled but this may either be due to the surface being closely wrinkled through shrinkage. As in the subdermal zone, at the periphery of some ground tissue patches there occur palisade-like rows of cells.

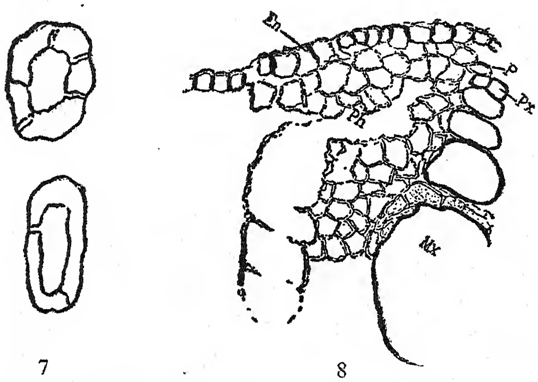
Details	Cortex	Dermal	Subdermal	Central
1 Cells of the ground tissue (average 30 counts)	·04 × ·04 mm.	·08 × ·05 mm.	·08 × ·06 mm.	·09 × ·07 mm.
2 Palisade cells (average 30 counts)	..	·1 × ·04 mm.	·17 × ·07 mm.	·19 × ·09 mm.
3 Fibrovascular bundles (average 30 counts)	·4 × ·5 mm	·9 × ·85 mm.	1·0 × ·75 mm.	1·0 × ·85 mm.
4 Width of the ground tissue in between the lateral sides of 2 fibro-vascular bundles	·09 mm.	·07 mm.	·15 mm.	·3 mm.
5 f/v ratio ..	5/1	15/1	22/1	23/1
6 Fibres of the dorsal sclerenchyma	·02 × ·02 mm.	·02 × ·02 mm.	·02 × ·02 mm.	·02 × ·02 mm.
7 Distribution of the fibrovascular bundles per cm.^{2}	..	105	75	68

Roots

It is fortunate that the roots of this species have been found in organic connection with the stem. They form a compact zone about 8 cm. thick round the basal part of the stem (Photo, 15) and are often

pressed against each other. They are 4 to 8 mm. thick, usually deformed by crowding, but some of them retain their circular form (Photo. 16).

The outermost layers are indistinguishable. The outer cortex (Photo. 17 Oc.), nearly ·6 mm. in width, is made up of fibres about ·02 mm. thick with a very small lumen ; the inner is about 2 mm. wide, of isodiametric parenchymatous cells. The peripheral portion of the inner cortex (Photo. 18, 1) is very compact with scattered cells, having black contents of indeterminable nature. The remaining portion of the inner cortex is about 1·5 mm. in width (Photo. 17, 2) and contains big lacunar spaces (A) which intercommunicate with each other. Such a conspicuous existence of parenchyma may suggest a marshy habitat.



7 8

Text-Figs. 7–8. Fig. 7. Idioblasts from the ground tissue. × 205. Fig. 8. Part of stele of root, end, endodermis : *P.*, pericycle ; *Mx.*, metaxylem ; *Px.*, Protoxylem ; *Ph.*, Phloem. × 130.

The innermost layer of the cortex is the fairly prominent single-layered endodermis with characteristic casparian strips (Text-fig. 8 En).

In the stele the pericycle forms one or two layers of cells (Text-fig. 8, P). Nearly two dozen xylem bundles are present, each with three or four vessels placed end to end, the outer ones constituting the protoxylem (Text-fig. 8, Px), the inner metaxylem (Text-fig. 8, Mx). Phloem is often disorganised and occurs as radially elongated patches between the xylem bundles (Text-fig. 8, Ph.). The metaxylem elements are surrounded on their inner and lateral sides by sclerenchymatous tissue which forms the outer pith. The centre of the pith is always seen more or less disorganised and sometimes there is an appearance as if this part is occupied by thin-walled parenchyma. A careful examination of different roots, however, shows that this appearance is only due to the disorganisation of the thickening layers of the fibrous walls.

Comparison with the type specimen of P. sclerodermum *Sahni.*

As the central region is not present in the type specimen, the comparison is necessarily limited to the outer zones only.

The cortex of both the specimens is similar in having both fibrous and fibrovascular bundles of different sizes with stegmata round them. It is, however, not possible to compare the ground tissue, as the type specimen includes only a narrow zone (6 mm.) of this region and the tissue is very badly preserved there.

Next, coming to the dermal zone it is seen that the frequency of the fibrovascular bundles is almost identical in this specimen (108 per cm.^{2} in the type specimen and 105 in the present one). Their form, size and average diameter are also very similar and so is the fibrovascular ratio which varies only between 12/1–18/1. The occurrence of stegmata both on the fibrous and fibrovascular bundles, the presence of a lacunar ground tissue which is made of compact thin-walled isodiametric cells, and the characteristic form of the leaf-trace are again features which indicate a close affinity between the two.

Extending our comparison to the subdermal zone, we again find that the fibrovascular bundles are of a similar size (1 mm. in both) but there is a slight difference in their frequency : about 65 per cm.^{2} in the type specimen and 75 in the corresponding region of our fossil. This variation, however, may be considered negligible as the frequency of the bundles may easily vary within the same zone along different radii, even in one and the same tree. Similarly, the slight variation observed in the *f/v* ratio (18/1–25/1 in the type specimen and 18/1–22/1 in the Nagpur specimen) need not be attached any great importance. The median sinus in both the specimens is cordate and stegmata are present both on the fibrous and the fibrovascular bundles.

The greatest resemblance is seen in the ground tissue which in both the specimens is lacunar and made up of thin-walled, rather isodiametric and lobed cells, with idioblasts scattered among them here and there. In my specimen I have described some palisade cells in the ground tissue of the subdermal zone. These are not recorded in the type specimen, but as stated, that specimen includes only a very small peripheral portion of the subdermal zone. The form and structure of the leaf-traces is essentially similar in the two specimens.

The central zone, as stated above, is not present in the type specimen, but from the details available in the specimen here described it is observed that there is hardly any difference between the subdermal zones of either of the two specimens and the central zone available in this material except for the irregular orientation and smaller frequency of the fibrovascular bundles.

The conclusion is therefore fully justified that the specimen here described is specifically identical with *P. sclerodermum* Sahni.

Palmoxylon sclerodermum–Sahni

(Plates VI-IX ; Text-figs. 2–8)

Diagnosis : Cortex—Cells of the ground tissue in the cortex radially elongated and arranged in tiers, fibrovascular bundles scattered, fibrous bundles present. Stegmata on both the fibrous and the fibrovascular bundles.

Dermal zone—Fibrovascular bundles in the dermal region flattened against each other and distorted, normally orientated, nearly 105 per cm.,^{2} ·4 to 1 mm. in diameter, xylem usually consists of a single median vessel, phloem very badly preserved and wedged in the cordate median sinus, *f/v* ratio 9/1–18/1 : fibrous bundles present, stegmata both on the fibrous and fibrovascular bundles : ground tissue lacunar, compressed in between the fibrovascular bundles, made of isodiametric thin-walled cells, leaf-traces tangentially cut and appear radially stretched with well-developed xylem projecting as a tongue-like process.

Subdermal zone—Fibrovascular bundles of the subdermal zone not compressed, round or elliptic, nearly 85 per cm.,^{2} mostly normally orientated, about 1 mm. in diameter, *f/v* ratio nearly 20/1, auricular lobes rounded or at times merge into the sides of the xylem elements, base of the dorsal sclerenchyma distinctly cordate, in xylem usually two large median vessels placed side by side. Phloem very badly preserved ; fibrous bundles present ; stegmata present both on the fibrous and fibrovascular bundles. Ground tissue lacunar, compact, of isodiametric slightly lobed cells ; palisade cells also occur at places. Leaf-traces as in the dermal zone.

Central zone—Fibrovascular bundles in the central zone quite free, nearly 75 per cm.^{2}, usually round, irregularly orientated, about 1 mm. in diameter, in other respects very like those of the subdermal ; fibrous bundles present ; stegmata both on the fibrous and fibrovascular bundles. Ground tissue very like in the subdermal, slightly larger. Leaf-traces absent.

Roots—4–8 mm. in diameter, outer cortex sclerenchymatous, inner made of compact cells at the periphery but very much lacunar on the inner side, 20–24 bundles in the stele, each bundle made of 3–4 vessels. Phloem (badly preserved) in the form of elongated patches between the xylem bundles, pith sclerenchymatous.

Localities—(1) Type specimen (coll. Burton), Seoni, Chhindwara district, (2) The present specimen (coll. Sagreiya) Nawargaon, Wardha.

Horizon—Base of the Deccan Intertrappean Series (Eocene). Reg. No. F/275 (present specimen).

Affinities

Now, as the anatomy of the complete specimen is known, the present species on the basis of the median cordate sinus of the dorsal *sclerenchyma* might be referred to the group *Cordata* of the Corypha-like palms in Stenzel's classification (1904, pp. 149–51). But by studying only some of the outstanding features of three known species under this group, it can be concluded that the present species is entirely different from any of them.

Comparison with Cordata *group.*

P. Fladungi Unger and *P. angulare* Cotta differ from the present species in having a much protruding vascular part of the fibrovascular bundle and in the absence of fibrous bundles. *P. geanthraci* (Göppert) Stenzel differs in having an ovate fibrous part in the fibrovascular bundles and numerous fibrous bundles.

Comparison with Cocos-*like palms.*

On the basis of the distribution of the fibrovascular bundles alone our species may perhaps also be referred to the *Cocos*-like palms but there is hardly any species in this class which may show any affinity with our type. At the same time the maximum resemblance of our species as shown by Professor Sahni can be traced to *P. densum* (Unger) Schenk, a Tertiary species from the West Indies, though it has been assigned by Stenzel to an entirely different class, *viz.*, the *Mauritia*-like palms. We shall study the comparison with this species in some detail.

Comparison with P. densum *(Unger)-Schenk.*

The points of resemblance between our species and *P. densum* have already been given by Prof. Sahni in his account of the type-specimen. These include the resemblance in the general appearance and distribution of the fibrovascular bundles, the presence of usually a single median vessel in the peripheral bundles and of a pair or more in the inner ones, the sculpturing of the xylem vessel, presence of the fibrous bundles and of stegmata round them, the general form of the leaf-trace, particularly with its long tongue-like process and the ventral sclerenchymatous arc. These points of resemblance, I too have observed in my material.

The points of difference from *P. densum* as observed by Prof. Sahni refer to the size of the fibrovascular bundles from periphery towards the centre, the form of the median sinus (reniform in *P. densum* and cordate here), auricular lobes (acute angled in Stenzel's form and obsolete in ours), presence of stegmata (only on the fibrous bundles in *P. densum*), idioblasts (absent in Stenzel's type) and the nature of the ground tissue (unlobed in *P. densum*).

Stenzel, in referring *P. densum* to the category of *Mauritia*-like palms surmised that if the central part of the stem of this extinct species were to be found, it would show a very sparse distribution of bundles and a *f/v* ratio smaller than in the outer bundles. Assuming that this surmise of Stenzel is correct, there would be the following additional dissimilarities :

(1) In our species the inner bundles are certainly not far apart and (2) There is a constant increase in the *f/v* ratio from the periphery towards the centre in our type. Thus summing up, it may be said that though there are several resemblances between the two types the differences from *P. densum* are too great to be overlooked.

From the above discussion two main conclusions emerge :—

(1) That the basis of Stenzel's classification is essentially unsound is clear from the fact that although *P. sclerodermum* has a cordate median sinus and would therefore be referred to the class *Cordata*, its maximum resemblance in other characters can be traced to *P. densum* which Stenzel has assigned to quite a different section.

(2) While on the basis of bundle distribution *P. sclerodermum* approaches the *Cocos* type, *P. densum*, with which at present it shows the nearest resemblance, has a totally different bundle distribution.

Thus we can say that the form, size and distribution of the fibrovascular bundles alone, may not be considered as diagnostic features of sufficient value for the classification of palms. Reference to this point has also been made in the past by the author in connection with the investigation of *Palmoxylon Kamalam* Rode (Shukla, 1939, p. 499).

SUMMARY

On the basis of a more complete specimen than the type-specimen, the species *P. sclerodermum* Sahni is redescribed in the present paper. In addition to the investigations made by Professor Sahni, the anatomy of the leaf-base region (the cortex), the central region and also the roots of this species has been studied. It has thus been possible to establish a more complete diagnosis for the species.

A comparison of this specimen with others described by Stenzel confirms the fact, which he admits, that the basis of his classification is an artificial one.

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EXPLANATION OF PLATES

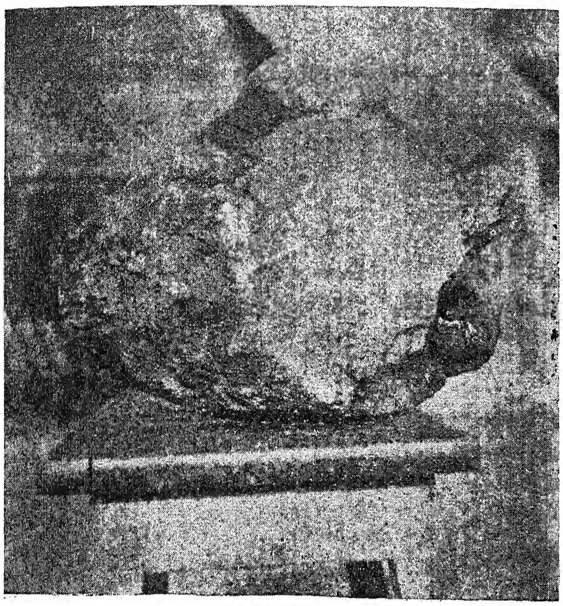
Plate VI. Photo. 1. *Palmoxylon sclerodermum* Sahni (×1/6).

Photo. 2. Transverse section through a part of the stem including C, cortex region ; D, dermal region ; S.D., subdermal region (×3).

Photo. 3. Part of transverse section through the cortex (×15).

Photo. 4. Part of transverse section through the dermal region showing compressed fibrovascular bundles Lt., leaf-trace (×25).

Plate VII.	Photo. 5.	Entire transverse section through the upper part of the stump; C, cortex; D, dermal; Sd., subdermal; N, Central zones (×6/7).
Plate VIII.	Photo. 6.	Transverse section through the subdermal region (×25).
	Photo. 7.	A patch of ground tissue from the subdermal zone; R, palisade cells in the ground tissue (×70).
	Photo. 8.	Part of transverse section through the central zone showing irregular orientation of fibrovascular bundles (×25).
	Photo. 9.	Part of the ground tissue from the central region showing slightly lobed cells; F, a fibrous bundle (×140).
	Photo. 10.	A typical fibrovascular bundle with its surrounding ground-tissue from the central region as seen in transverse section; T, tabular parenchyma at the periphery of the bundle (×50).
Plate IX.	Photo. 11.	Longitudinal section showing S, a row of stegmata with dorsal sclerenchyma to its left and parenchyma to the right; (×140).
	Photo. 12.	Longitudinal section showing a vessel with its scalariform end wall (W) (×140).
	Photo. 13.	Longitudinal section through the stem of *P. sclerodermum* Sahni showing S, rows of stegmata on the dorsal sclerenchyma cut tangentially with parenchyma on the right (×140).
	Photo. 14.	Longitudinal section showing a vessel with reticulate thickening (R) (×210).
	Photo. 15.	Basal part of *P. sclerodermum* Sahni; R, roots fractured transversely (×1/4).
	Photo. 16.	Transverse section through a group of roots seen in Photo. 16 (×3/2).
	Photo. 17.	Transverse section through the root, O.C., outer cortex; I.C., inner cortex; 1, peripheral part of the inner cortex; 2, central part of the inner cortex; A, lacunar spaces; L, phloem; P, pith. (×25).



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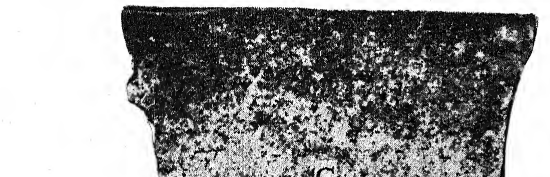

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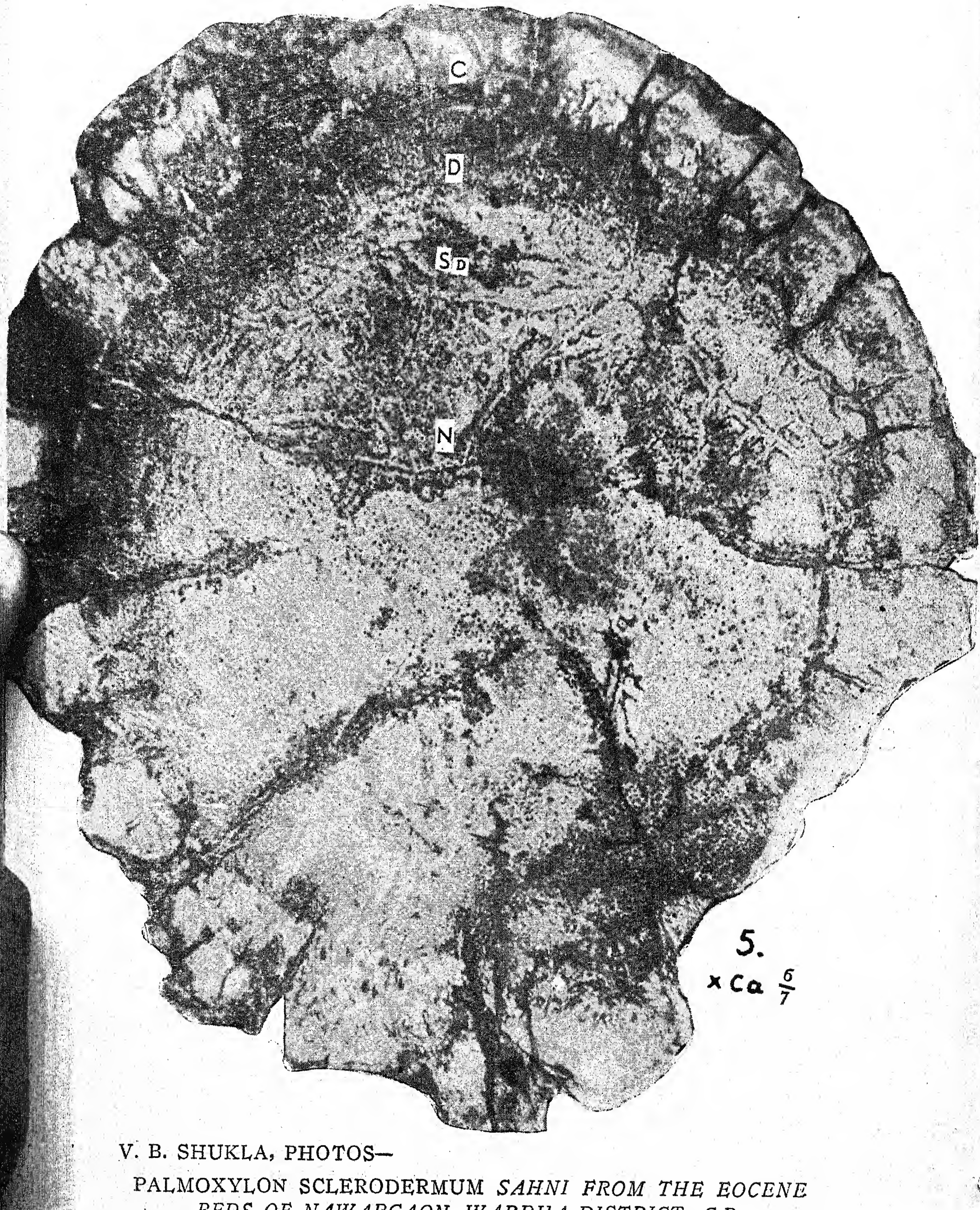
V. B. SHUKLA, PHOTOS—

PALMOXYLON SCLERODERMUM *SAHNI FROM THE EOCENE BEDS OF NAWARGAON, WARDHA DISTRICT, C.P.*



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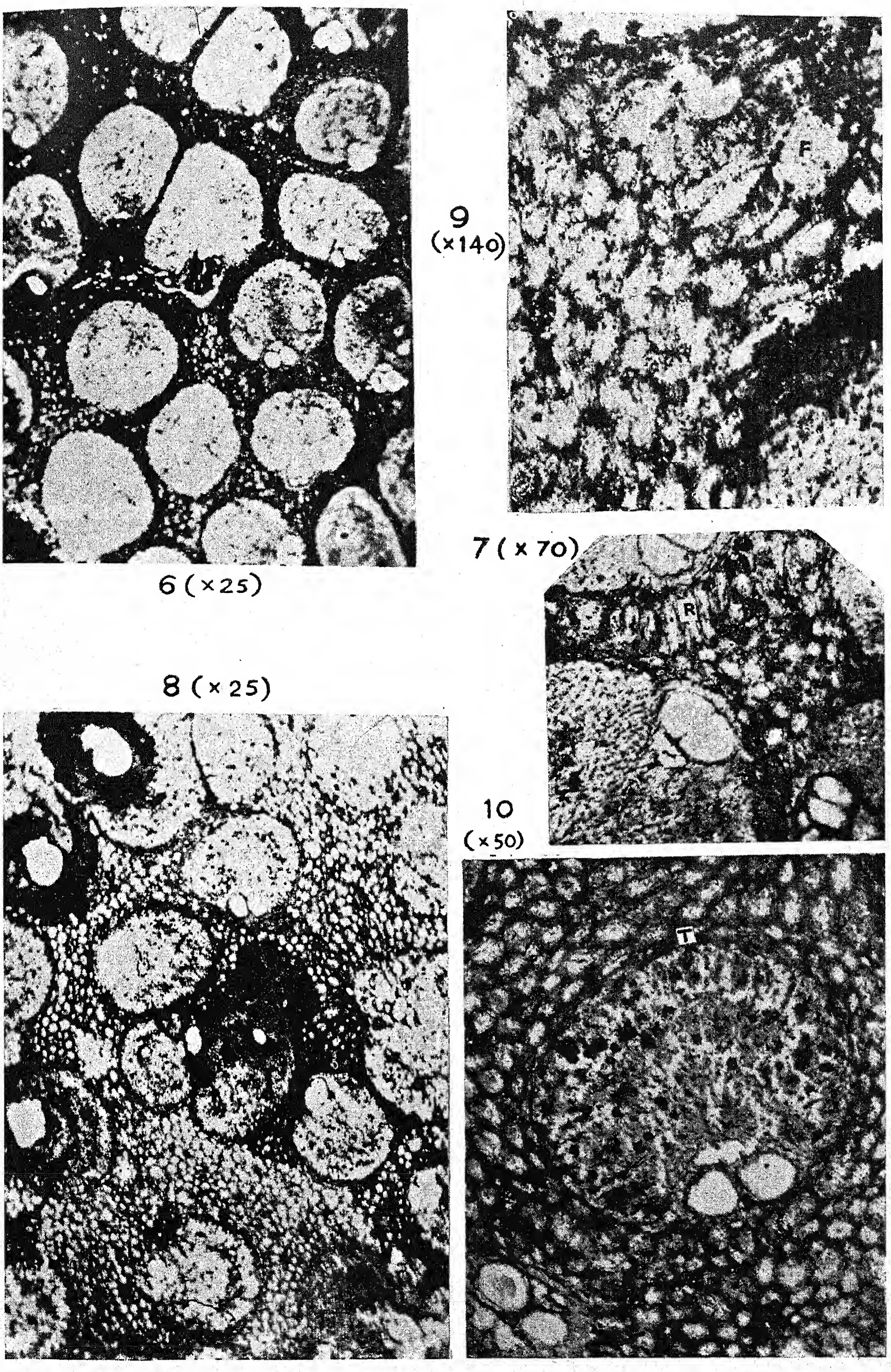

V. B. SHUKLA, PHOTOS—

PALMOXYLON SCLERODERMUM *SAHNI FROM THE EOCENE BEDS OF NAWARGAON, WARDHA DISTRICT, C.P.*

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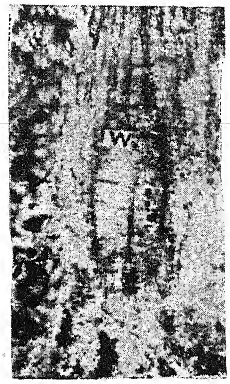

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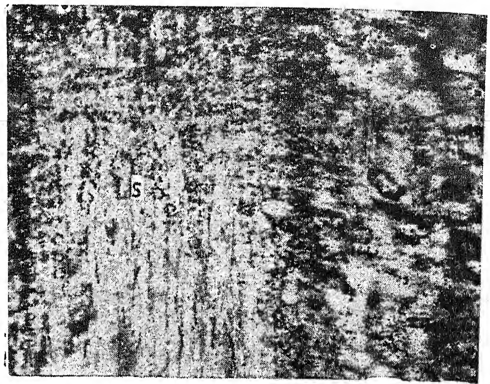

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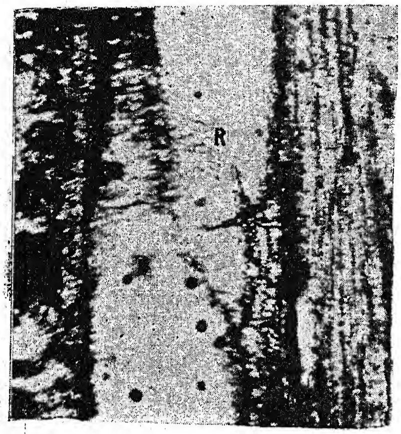

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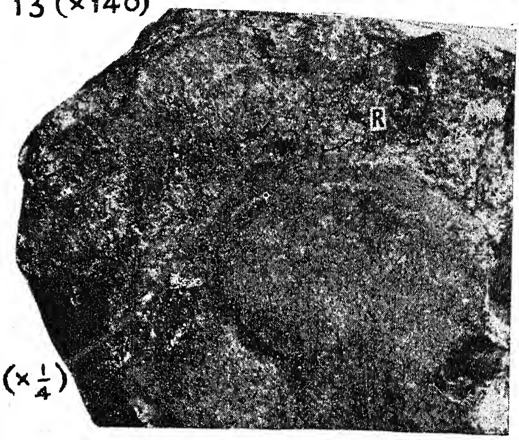

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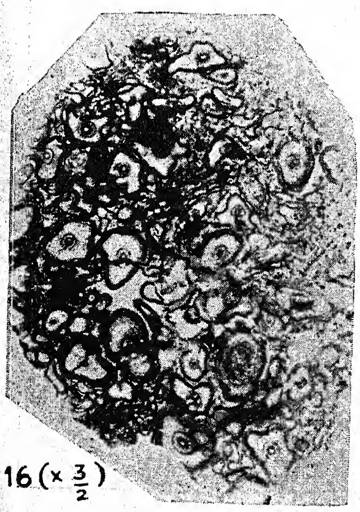
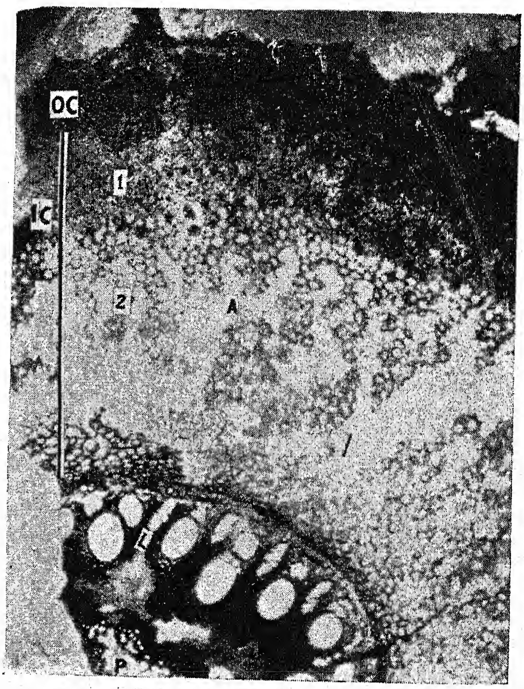


16 (×$\frac{3}{2}$)



17 (×25)

V. B. SHUKLA, PHOTOS—

PALMOXYLON SCLERODERMUM *SAHNI FROM THE EOCENE BEDS OF NAWARGAON, WARDHA DISTRICT, C.P.*

ON *JOHANNESBAPTISTIA PELLUCIDA* (DICKIE) TAYLOR AND DROUET FROM MADRAS

By M. O. P. Iyengar and T. V. Desikachary

University Botanical Laboratory, Madras

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In 1927, Gardner recorded from Porto Rico two blue-green algæ which he referred to a new genus, *Cyanothrix* (non *Cyanothrix* Schmidle), and called the two algæ *C. primaria* and *C. Willei.* Taylor described in 1928 an alga from Dry Tortugas under the name *Nodularia* (?) *fusca* sp. nov. Frémy (1935, p. 96) with regard to this new species says that Taylor evidently had no knowledge at the time of the establishment of Gardner's *Cyanothrix*, otherwise, he (Taylor) would have doubtless made it a *Cyanothrix* intermediate in dimensions between *C. primaria* and *C. Willei.* De Toni, in 1934, renamed Gardner's genus *Cyanothrix* as *Johannesbaptistia* (Gardner) De Toni, since the name *Cyanothrix* had already been given by Schmidle (1897, also 1898) for an alga (*Cyanothrix vaginata*), which is now included under the genus *Mastigocladus* Cohn. Frémy (1935) found in some algal collections from the Isle of Bonaire and Algeria a *Johannesbaptistia* which showed characteristics of all the three species, *viz.*, *J. primaria* (Gardner) De Toni, *J. Willei* (Gardner) De Toni and *Nodularia* (?) *fusca* Taylor, and so combined all these three under one species, *J. Gardneri* Frémy comb. nov. Two years later Seurat and Frémy (1937, p. 294) recorded this alga from South Tunisia also.

Drouet, in 1936, made a detailed study of a collection of *Johannesbaptistia* from the Galapagos Islands and also the original materials of Gardner and Taylor. He agreed with Frémy's combination of all the known species under one species, but preferred to use the name *J. primaria* (Gardn.) De Toni instead of *J. Gardneri* Frémy for nomenclatural considerations. Taylor (Drouet, 1938) from an examination of authentic material of *Hormospora pellucida* Dickie (Dickie, 1874) came to the conclusion that *H. pellucida* was really a *Johannesbaptistia.* Taylor and Drouet (Drouet, 1938), therefore called the alga *Johannesbaptistia pellucida* (Dickie) Taylor and Drouet and made *J. primaria* (Gardn.) De Toni (*J. Gardneri* Frémy) a synonym of it.

The writers found a *Johannesbaptistia* in a collection of algæ from a brackishwater pool at Ennore, a place about 10 miles north of Madras. This genus does not appear to have been recorded so far from India. A detailed account of the alga is given here.

The alga is filamentous and has a broad mucilaginous sheath. The sheath is hyaline and not refractive. Occasionally its outer limits

are very gelatinous and have debris sticking on to them. It is not stained with congo red nor coloured blue with iodine and sulphuric acid. It is stained with safranin, methylene blue or gentian violet.

The cells of the alga are arranged in a single series and are separated from each other by mucilage so that the alga appears as a single series of separate cells imbedded in a homogeneous cylindrical gelatinous matrix (Text-figs. 1, 5–6 ; Pl. X, Fig. 3). The cells divide in a plane at right angles to the longitudinal axis of the filament. Immediately after division, the two daughter cells are seen attached to each other, but soon after, they become separated from each other. No protoplasmic connections could be seen between adjacent cells of the filament in spite of very careful examination under higher powers either with or without staining. The cells are discoid or roughly hemispherical with plane or convex faces and are nearly circular in cross-section. The cell-contents are granular and blue-green in colour.

When stained with very dilute aqueous methylene blue, safranin or gentian violet, each cell shows a mucilaginous envelope round it inside the common mucilaginous sheath of the filament. When a cell divides, the mucilaginous envelope of the mother-cell is seen clearly round the two closely apposed daughter cells. Each of these daughter cells soon secretes its own mucilaginous envelope inside the envelope of the mother-cell somewhat as in *Gloeœapsa* or *Chroococcus* (Text-figs. 3 and 4 ; Pl. X, Figs. 1 and 2). The envelope of the mother-cell can be seen distinctly though faintly stained for some time, but finally becomes indistinguishable from the general mucilage of the filament.

The filament is 7·9–9·2 (10·8) μ broad and attains a length of 400 μ and sometimes even up to 2500 μ. The cells are 3·9–5·2 μ broad and 2·6–3·9 μ long.

Some of the cells of the filament degenerate and the filament fragments at these places (Text-fig. 1). Often a filament gets fragmented into quite a number of smaller bits (Text-fig. 2). Occasionally bits consisting of only two cells even are seen (Text-fig. 5). These fragments evidently serve for purposes of vegetative propagation.

The dimensions of the filaments and cells of the present alga [filament 7·9–9·2 (–10·8) μ broad and cells 3·9–5·2 μ broad] come within the range of the dimensions given by Drouet for *J. pellucida* (Dickie) Taylor and Drouet (filament 8–23 μ broad and cells 4–17·5 μ broad). The writers, therefore refer the alga to *J. pellucida* (Dickie) Taylor and Drouet.

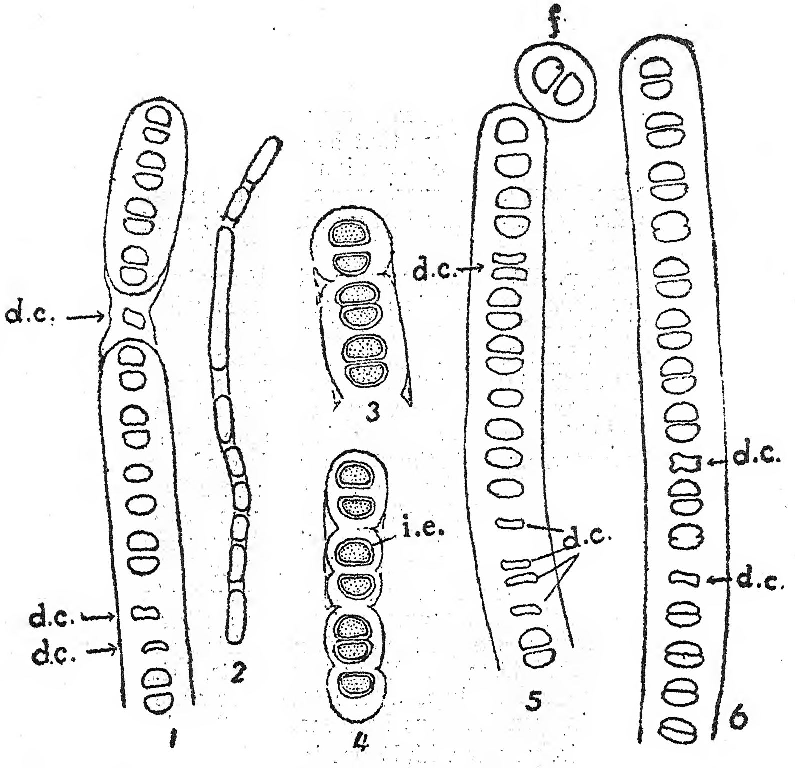
Gardner (1927) placed his new genus *Cyanothrix* in the Chroococcaceæ. Geitler (1932, p. 456) kept it under 'Anhang' at the end of the Chamæsiphonales, and suggested that it might be referred to the Entophysalidaceæ. Frémy (1935) removed the genus from the Chroococcaceæ and placed it in the Hormogonales in the family Oscillatoriaceæ between *Oscillatoria* and *Lyngbya* on account of its general resemblance to an Oscillatoriaceæ and also the similarity of its fragmentation through the death of one or more cells to hormogone formation. But he brushes aside the most important feature of *Johannesbaptistia*, *viz.*, the separate condition of the cells of the filament,

by stating that he considers it only as a biological condition, since he found, in some very thin filaments (1–2 μ thick) of an Oscillatoriaceæ from Bonaire Islands, some of the cells were contiguous while others were free as in *Johannesbaptistia.* He mentions that he found all transition stages between *Lyngbya infixa* Frémy and *Johannesbaptistia.* He states, however, at the same time that he cannot pronounce categorically on this point, since his observations were rendered difficult on account of the smallness of the specimens and also the lack of sufficient material. He finally states that further research is needed to decide this point.

Drouet (1936, p. 20) does not agree with Frémy's suggestion that the filaments of *Johannesbaptistia* are comparable with those of a *Lyngbya* in which the cells are separated from each other as a biological condition, since in his (Drouet's) experience such a separation of cells in any filaments of the Homocysteæ is usually accompanied by other pathological characteristics, such as, loss of pigment, change in shape of cells and production or loss of protoplasmic granules. With regard to Frémy's comparison of the fragmentation of the filaments in *Johannesbaptistia* through the death of one or more cells to hormogone formation in the Hormogonales, Drouet states in reply that such a resemblance cannot form a basis for including *Johannesbaptistia* in the Hormogonales, since, if Frémy's contention were to be accepted, then one may rightfully transfer at once to the Hormogonales any of the Entophysalidaceæ or Pleurocapsaceæ as soon as a filament is seen to break up into segments through the death and disintegration of a cell or cells within the filament. Drouet suggests, therefore, that *Johannesbaptistia* should be kept in the Chroococcaceæ until further and more elucidating studies have been made of the alga.

The writers entirely agree with Drouet's view that *Johannesbaptistia* should be kept in the Chroococcaceæ. They have other evidence also in support of this conclusion. As already stated, specimens of the alga stained with very dilute aqueous safranin, methylene blue or gentian violet show a definite mucilaginous envelope round *each* cell inside the general mucilaginous sheath of the filament. And, when a cell divides, each of the two daughter cells very soon secretes a mucilaginous envelope round itself inside the envelope of the mother-cell, somewhat as in *Glœocapsa* or *Chroococcus.* Taylor states that the filaments of *Nodularia* (?) *fusca* occasionally showed 'individual sheaths round pairs of cells'. Frémy (1935, p. 96) states with regard to this feature that they are only biological peculiarities, and further comments that these cells have not been figured by Taylor. The writers do not agree with Frémy that these are only biological peculiarities since they find that this is a constant and characteristic feature in the present alga.

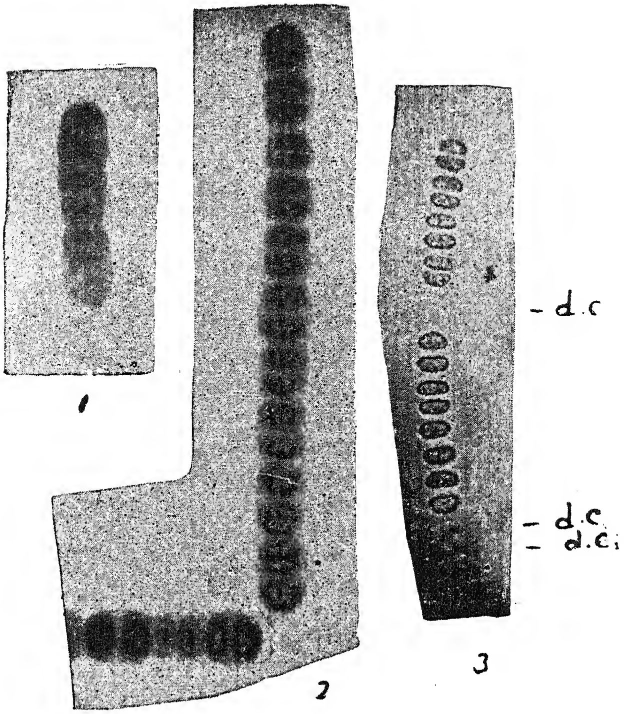
The fact, that the cells are separate and each of them possesses its own mucilaginous envelope round itself inside the common mucilaginous sheath of the filament, and that, when a cell divides, each of the two daughter cells secretes an envelope of its own inside the mother-cell envelope clearly shows that the alga belongs to the Chroococcales and not to the Hormogonales.



Text-Figs. 1-6. *Johannesbaptistia pellucida* (Dickie) Taylor and Drouet.

Fig. 1. Portion of a filament. Note the fragmentation near a dead cell. Same filament as in Plate X, Fig. 3. Fig. 2. A long filament which is breaking up into a number of fragments drawn under low power. Cells not shown. Fig. 3. Portion of a filament drawn after staining with safranin showing the common mucilage as well as the individual envelopes. Fig. 4. A short filament stained with safranin showing the common mucilage as well as the individual envelopes. Same as in Plate X, Fig. 1. Figs. 5 & 6. Portions of filaments; in Text-fig. 5 a two-celled fragment, just separating from the end portion. (*d.c.*, dead cell; *i.e.*, individual envelope; *f.*, fragment.). Text-figs. 1, 3–6, × 1165; Text-fig. 2, × 300.

This alga in the writers' opinion clearly belongs to the Chroococcales and is a filamentous development among the Chroococcales. Such a filamentous condition can easily be derived from a Chroococcaceous condition by the limiting of the cell-division to one plane only. The filamentous condition of *Johannesbaptistia* must be considered as merely a parallel development among the Chroococcales. A filamentous tendency is already seen in some of the members of the Entophysalidaceæ (see Fritsch, 1945, p. 819; Geitler, 1932, p. 293). The genus *Johannesbaptistia* may be considered as the highest expression of the filamentous tendency among the Chroococcales. The writers, therefore, agree with Gardner (1927), Geitler (1932) and Drouet (1936) that *Johannesbaptistia* should be kept in the Chroococcales. They



Figs. 1 and 2. Filaments stained with safranin showing the mucilaginous envelope round individual cells and also round pairs of daughter cells.

Fig. 3. An unstained filament showing fragmentation; note dead cells (*d. c.*) at the region of fragmentation.

All × 850.

M. O. P. IYENGAR AND T. V. DESIKACHARY—

JOHANNESBAPTISTIA PELLUCIDA (*DICKIE*) *TAYLOR AND DROUET FROM MADRAS*

therefore retain the original diagnosis of the genus *Johannesbaptistia* (Gardn.) De Toni and are unable to accept the emended diagnosis of the genus of Frémy (1935, p. 99). They suggest that the genus may be placed in the Entophysalidaceæ along with other algæ which show a filamentous tendency.

Summary

An account is given of *Johannesbaptistia pellucida* (Dickie) Taylor and Drouet. The alga was collected at Ennore near Madras. This appears to be the first record of this genus in India.

The writers do not agree with Frémy's suggestion that the genus *Johannesbaptistia* should be placed in the Oscillatoriaceæ between *Oscillatoria* and *Lyngbya*, but agree with Drouet's suggestion that it should be retained inside the Chroococcales.

The filamentous condition in *Johannesbaptistia* should be considered as a parallel development among the Chroococcales. *Johannesbaptistia* represents the highest expression of the filamentous tendency among the Chroococcales.

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SOME STUDIES ON THE SMUT, *USTILAGO COICIS* BREF., OF JOB'S TEARS MILLET

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Received for publication on January 22, 1946

I. Introduction

Job's tears millet (*Coix lachryma-jobi* L.) is an important cereal in the Central Provinces, Sikkim, Assam and Burma and the plant is grown as a regular field crop. The plant is very hardy in nature and thrives upon almost any kind of soil, yielding a good amount of produce. In taste, the cereal resembles wheat. In Assam the plant is grown in Khasi, Garo and Naga Hills. The grain is roasted, then husked and eaten whole, either parched or boiled. The grain is also milled and ground to flour and baked into bread. It is also used as a poultry feed and in the Naga Hills utilized for the manufacture of a beer called *dzu* which is highly prized for its fruity flavour and delicate aroma.

The plant is susceptible to a smut, *Ustilago coicis* Bref., in the Khasi Hills and is affected every year. The disease is widespread and causes considerable damage. Estimates made have revealed that the damage caused usually amounts from 12 to 25 per cent. and in extreme cases the loss amounts to more than 35 per cent. Every grain of the head is transformed into a black spore mass, without much increase in size as compared with the healthy grains. The spore mass is surrounded by a membrane hidden by the glumes and is traversed by flattened or angular filaments probably the remains of the fibro-vascular bundles of the axis. The fungus is ovaricolous and completely destroys the ovaries, all of which in a raceme are destroyed. Plate XI shows the symptoms of the disease.

Mundkur (1941) has reported a second smooth-spored smut on this millet which he calls *U. lachryma-jobi* Mundkur from Girnar Hills but this smut has not so far been observed to occur in Assam.

II. Morphology of Spores

The sori are 9–13 mm. long and 5–9 mm. broad, brown-black in colour and contain a pulverulent spore mass. Spores are held together by the hard floral glumes. The spores (Fig. 1) are liver-brown, subglobose to ellipsoidal with minute but clear echinulations which give the margin a serrate appearance; rather prominent circular pits are also present on the epispore. The spores are 7–13 μ (mean $9 \cdot 1$ μ) in diameter.

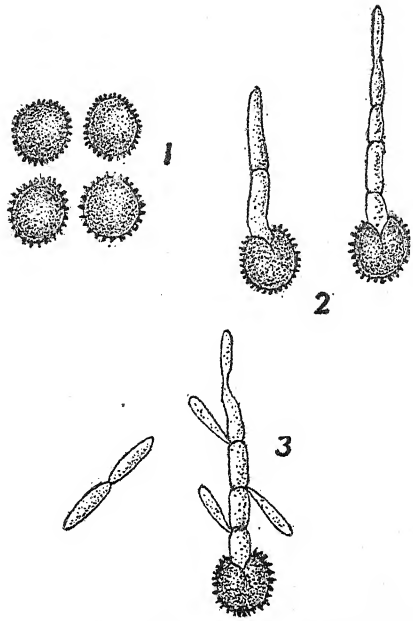

Fig. 1. Spores. Fig. 2. Germination of spores with formation of promycelium. Fig. 3. Germination of spores with formation of sporidia.

III. Germination of Spores

The spores germinate freely in water or nutrient solutions as soon as mature. The spore on germination gives rise to a promycelium which is always four-celled (Fig. 2). Sporidia (Fig. 3) are formed terminally and laterally near the septa and these may bud off secondary sporidia. The primary sporidia often elongate into a septate filament which may be longer than the promycelium and which also buds off secondary sporidia from the ends and from near the septa.

(i) *Effect of nutrient solutions on germination.*—The spores were germinated at 25°–26° C. in glucose and sucrose solutions, in Job's tears leaf-juice, soil extract, dung extract and distilled water. Job's tears leaf-juice was prepared by steaming for half an hour 20 grams of green leaf in 100 c.c. of distilled water ; soil extract was obtained by dissolving 10 grams of soil in 100 c.c. of distilled water allowing the solution to stand for 24 hours and then filtering through ordinary filter paper ; cowdung extract was prepared by shaking 10 grams of it in 100 c.c. of distilled water, allowing it to stand for 24 hours and then filtering through ordinary filter paper. The results obtained are recorded in Table I.

It will appear from the data presented in Table I that the nutrient solutions exerted a favourable influence on spore germination and the percentage of germination was more in all the nutrient solutions than

TABLE I

Effect of nutrient solutions on spore germination

Media	Percentage of germination after	
	24 hours	48 hours
2% glucose solution ..	17	49
5% ,, ,, ..	29	79
2% sucrose ,, ..	16	52
5% ,, ,, ..	31	81
Job's tears leaf-juice ..	28	65
Soil extract ..	27	67
Cow-dung extract ..	29	62
Distilled water ..	12	27

in distilled water. Five per cent. glucose and five per cent. sucrose solutions were found better than 2 per cent. solutions of these sugars. Job's tears leaf-juice, soil extract and cow-dung extract were almost equally effective, the difference being very little though inferior to 5 per cent. sugar solutions.

(ii) *Effect of temperature on germination.*—The spores were germinated in 5 per cent. glucose solutions at temperatures ranging from 5° to 40° C. The results obtained are recorded in Table II.

TABLE II

Germination of smut spores at different temperatures

Temperature (C.)	Percentage of germination after	
	24 hours	48 hours
5	..	..
15	14·9	56·4
20	16·2	71·4
25	29·8	89·2
30	45·8	94·0
35	23·7	45·8
40	..	..

The results presented in Table II show that the optimum temperature for the germination of spores is about 30° C., the maximum between 35° and 40° C. and the minimum between 5° and 15° C.

(iii) *Effect of hydrogen-ion concentration on spore germination.*—The spores were germinated at 25° C. in 5 per cent. glucose solution having a hydrogen-ion concentration range varying from 3·0 to 9·0. Normal hydrochloric acid and normal sodium hydroxide solutions

were used to make different pH ranges and the hydrogen-ion concentration was determined by the calorimetric method. The observations are recorded in Table III.

TABLE III

Germination of smut spores at different pH values

Hydrogen-ion concentration	Percentage of germination after	
	24 hours	48 hours
3·0	30·0	82·1
3·8	31·2	80·0
4·2	29·0	79·2
5·2	35·2	88·7
6·0	46·9	91·7
6·4	52·8	97·5
7·0	43·4	89·2
7·7	40·2	87·7
8·4	32·8	82·8
9·0	27·8	74·2

From the results recorded in Table III it is clear that the germination of spores is very good over a wide pH range. The optimum hydrogen-ion concentration for spore germination, however, is 6·4.

IV. MODE OF TRANSMISSION OF THE DISEASE

The following pot and field experiments were carried out to study the mode of perpetuation of the disease.

(i) *Experiments to test seedling infection by seed-borne spores.* In 1943 the soil and pots used for the experiments were sterilized in an autoclave at 120° C. for two hours. Forty such pots were sown on 20th April with Job's tears seed which had previously been steeped in a 2 per cent. solution of formalin for 20 minutes, then dried and smeared with spores of the smut by shaking them in a glass vessel containing a thin paste made of spores in distilled water. Ten other pots were sown on the same day with Job's tears seeds similarly steeped in formalin solution and dried but not smeared with spores, to serve as controls. All the plants received upto the time of harvesting the same cultural treatment. On the 7th October the number of healthy and smutted plants was as given in Table IV, from which it will be seen that while the controls were free from smut, 25 per cent. of the seeds infected with smut spores gave smutted plants. The above experiment was repeated in 1944 with similar results, which are also contained in Table IV.

Another similar experiment was carried out in a small plot but the soil was not sterilized. It was known however that Job's tears millet was never grown before on this land or round about this field for a distance of about 50 miles. Seeds infected in the manner of the

TABLE IV

Summary of results of infection experiments carried out in pots

Year	Control				Infected seed			
	Total plants	Healthy plants	Smutted plants	Per cent. smut	Total plants	Healthy plants	Smutted plants	Per cent. smut
1943 ..	40	40	Nil	Nil	160	120	40	25·0
1944 ..	40	40	,,	,,	120	93	27	20·9

last experiments were sown in 7 rows on 15th April and 7 rows were sown with seeds treated as for the controls mentioned above, cultural treatments being kept the same for both. On the 5th October 29·6 to 35·7 per cent. of the plants were smutted in the infected rows while none of the others had smut.

TABLE V

Summary of field infection studies carried out with infected seeds

Rows of plants	Control				Infected seed			
	Total plants	Healthy plants	Smutted plants	Per cent. smutt	Total plants	Healthy plants	Smutted plants	Per cent. smut
1	102	102	Nil	Nil	98	63	35	35·7
2	96	96	,,	,,	108	76	32	29·6
3	64	64	,,	,,	96	66	30	31·2
4	82	82	,,	,,	112	72	40	35·7
5	112	112	,,	,,	127	85	42	33·1
6	75	75	,,	,,	116	81	35	30·1
7	107	107	,,	,,	99	67	32	32·3

The above experiment was repeated in 1944 with similar results. These results from pot and field experiments show that seed-borne spores are a source of infection in this smut.

(ii) *Experiments to test seedling infection by spores shed in the soil from the previous year's crop.*—On 27th October 1942 spores of smut from material collected on 7th October 1942 were mixed with the surface 2 to 3 inches of sterilized soil contained in 20 sterilized pots which were then placed in the open. On the 10th April 1943, disinfected Job's tears seeds were sown in them. Ten sterilized pots sown on the same day with disinfected seed but whose soil was infected with smut spores at sowing time, were arranged to serve as controls. The results recorded in October 1943 are presented in Table VI. Another similar experiment was carried out in a small plot but the soil was not sterilized. The plot was divided into two parts; on the 7th October 1942 spores of the fungus were mixed with the surface 2 to 3 inches of

the soil of one part of the plot and left fallow. On 10th April 1943 disinfected Job's tears seeds were sown on this and the other part of the plot, the soil of the latter being infected with smut spores immediately before sowing to serve as control. The results noted in October 1943 are also recorded in Table VI.

TABLE VI

Summary of soil infection experiments with smut spores

Treatments	Total plants	Healthy plants	Smutted plants	Per cent. smut
(*a*) *Pot Experiments*—				
Soil infected with spores at the time of sowing, April 1943 ..	40	28	12	30·0
Soil infected in October 1942 ..	80	80	Nil	Nil
(*b*) *Field Experiments*—				
Soil infected with spores at the time of sowing, April 1943 ..	329	234	95	28·8
Soil infected in October 1943 ..	346	344	2	0·58

These experiments were repeated in 1943–44 and exactly similar results obtained. These results show that the infection arising from spores carried in the soil from the previous year's crop is insignificant.

(iii) *Experiments to test floral infection.*—Fifty ears were bagged on fifty healthy plants of Jobs tears on 15th September 1943, thirty of which were dusted on three consecutive days, 20th, 21st and 22nd September 1943 with smut spores freshly collected each day. Each day after dusting a very little water was sprayed with an atomizer on the dusted ears which were then rebagged. The twenty other ears which were not dusted with spores were kept as controls.

Both the sets were unbagged on 20th October 1943 and the seeds collected from each kept separate. Each lot was then sown in two plots of land where Job's tears was never grown before. The seeds were disinfected before sowing in 2 per cent. formalin solution for 20 minutes ; sowing was done on 17th April 1944. The observations made are noted in Table VII.

TABLE VII

Summary of results of floral infection

Treatments	Total plants	Healthy plants	Smutted plants	Per cent. smut
Seed from infected flowers	387	387	Nil	Nil
Control ..	215	215	,,	,,

The results recorded in Table VII show that no infection comes from blossom infection.

From these experiments the conclusion arrived at is that the general mode of infection is seedling infection by seed-borne spores. When the seed germinates, the smut spores also germinate and the smut hyphæ penetrate the tissue of the seedling at once. The parasite keeps pace with the developing plant becoming conspicuous as black, sooty masses of spores which totally replace the flowering head. These studies further show that the chances of the disease being reproduced through soil-borne spores are remote and insignificant. This conclusion agrees with the finding of Thomas (1920), who first showed that this smut is seed-borne.

V. Control Measures

As the disease is primarily carried through infected seeds it is evident that to get a healthy crop it is necessary to sow only healthy seeds obtained from a disease-free locality or to disinfect the seeds, before sowing with such fungicides which will kill the smut spores adhering to the outside of the seeds without injuring the seeds. Four fungicides, namely, agrosan G, ceresan, formalin dust and copper carbonate dust were tested.

To test the efficacy of these fungicides an experiment was carried out at Sylhet in 1943. Naturally infected seeds were selected for treatments but they were given a further dose of artificial infection by shaking them in a glass vessel containing a thin paste made of smut spores in distilled water. The seeds were thereafter carefully shaken with the respective fungicides so that they got thoroughly and uniformly covered with the fungicides. The treatments were as follows :

(i) Control : Infected seeds.

(ii) Infected seeds treated with agrosan G at the rate of one part per 250 parts of seed by weight.

(iii) Infected seeds treated with ceresan at the rate of one part per 250 parts of seed by weight.

(iv) Infected seeds treated with formalin dust at the rate of one part per 200 parts of seed by weight.

(v) Infected seeds treated with copper carbonate dust at the rate of one part per 200 parts of seed by weight.

The treated seeds were sown immediately after treatments in April 1943. Randomised block system of lay-out was followed ; there were six replications. Each block contained five plots, each plot 10 ft. $\times$ 5 ft. in size. Each plot had twenty rows of plants and in each row there were twenty plants. At the time of harvest the number of smutted plants was carefully noted ; the percentage of smutted plants worked out is recorded in Table VIII.

It will be evident from the results presented in Table VIII that though none of the fungicides tried is able to control the disease completely, all of them are quite effective in holding the disease appreciably under check. In comparison with the percentage of smut in the control plots, the percentage of smut in the treated plots is insignificant. In order of efficacy the fungicides may be listed as follows : copper carbonate, formalin dust, agrosan G and ceresan.

TABLE VIII

Number and the percentage of smutted plants after seed treatments

Block	Control			Agrosan G			Ceresan			Formalin dust			Copper Carbonate		
	Total No. of plants	Smutted plants	Per cent. smut	Total No. of plants	No. of smutted plants	Per cent. smut	Total No. of plants	Smutted plants	Per cent. smutt	Total No. of plants	No. of smutted plants	Per cent. smut	Total No. of plants	No. of smutted plants	Per cent. smut
1 ..	400	130	32·5	400	6	1·5	400	8	2·0	400	3	0·75	400	1	0·25
2 ..	400	112	28·0	400	2	0·5	400	2	0·5	400	4	1·0	400	2	0·5
3 ..	400	121	30·25	400	2	0·5	400	2	0·5	400	2	0·5	400	0	0·0
4 ..	400	130	32·5	400	4	1·0	400	6	1·5	400	2	0·5	400	1	0·25
5 ..	400	108	27·0	400	3	0·75	400	3	0·75	400	3	0·75	400	2	0·5
6 ..	400	118	29·5	400	6	1·5	400	4	1·0	400	2	0·5	400	0	0·0
Mean	..	..	29·96	..	..	0·96	..	..	1·04	..	..	0·67	..	..	0·25

The experiments were repeated in 1944 and practically the same results obtained. Thus it can be safely concluded that the disease can be appreciably kept under control by treating the seeds with fungicides before sowing. To secure satisfactory results it is necessary that the seeds are thoroughly and uniformly covered by the fungicides.

VI. SUMMARY

Job's tears millet (*Coix lachryma-jobi*) is grown in Khasi, Garo and Naga Hills and is an exceedingly important cereal. The plant is susceptible to a serious smut due to *Ustilago coicis* in the Khasi Hills and occurs every year. The disease is wide spread and the damage caused usually amounts from 12 to 25 per cent. per annum.

The morphology of the spores has been described.

Influence of nutrient solutions, temperature and hydrogen-ion concentrations on the germination of the spores has been studied. The optimum temperature and hydrogen-ion concentration for spore germination is about 30° C. and 6·4 pH respectively.

The mode of transmission of the disease has been studied. It has been observed that the principal source of infection in this smut is the seed-borne spores.

Experiments on control measures consisted in treating the infected seeds before sowing with certain fungicides, namely, agrosan G, ceresan, formalin dust and copper carbonate dust. None of them was found able to completely control the disease but in comparison with the control plots the percentage of smut in the treated plots was insignificant; copper carbonate dust was found to be the best.

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Symptoms of the disease

S. CHOWDHURY—

SOME STUDIES ON THE SMUT, USTILAGO COICIS *BREF., OF JOB'S TEARS MILLET*

A LEAF SPOT OF *BORASSUS FLABELLIFER* L. CAUSED BY *PESTALOTIA PALMARUM* CKE.

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I. Introduction

Tál (*Borassus flabellifer*) is extensively grown in Assam for its fruit, the juice of which is used for the preparation of a special kind of delicious cake. The leaves are used for the manufacture of hand fans which command quite a wide and profitable market. The plant, however, suffers from a serious leaf spot caused by *Pestalotia palmarum* Cke., which kills almost the entire leaf and by thus destroying the food manufacturing apparatus of the plant makes it weak. A survey made during the past three years has revealed that in severe cases of leaf infestation the fruiting capacity of the plant is impaired. The disease also lowers very appreciably the value of the leaves as material for the manufacture of fans and in a great many cases makes them almost useless for the purpose.

The disease has been observed to occur throughout Assam; it has also been reported from Bombay by Uppal, Patel and Kamat (1935). Recently Mundkur and Kheswala (1942) have reported the occurrence of the parasite on *Areca catechu* L. in Chittagong, on *Borassus flabellifer* in Bengal and Bihar, on *Cocos nucifera* L. in Bengal and on *Phoenix sylvestris* Roxb. in Bombay and Bihar. In Assam, however, it has been observed so far only on *Borassus flabellifer*.

II. Symptoms of the Disease

In early stages of infection the disease is characterised by small, yellowish brown, circular to oblong, more or less depressed spots which are about a millimeter in diameter. The diseased areas gradually increase uniformly in length and width. The yellowish brown spots are seen surrounded by a grayish brown band which is about a millimeter in width. Sometimes this band does not extend completely around the spots. Within this brown band there is a cream-coloured portion which appears much thinner than the healthy parts of the leaf. In some cases the thinner central portion of the spots appear dark brown. The lesions tend to grow in length parallel to the veins.

In advanced stages of the disease the spots may be as large as five centimeters long and one or more centimeters wide. The central portion of the spot becomes gray. The brown band at the border becomes dark brown. Two to five or more spots may coalesce forming larger, irregular gray dead areas. On the upper surface of the leaf,

black minute dot-like bodies consisting of the fruiting structures of the fungus soon appear on the grayish center. Both young and old spots spread rapidly under damp humid conditions. If the air is very dry, the lesions develop very slowly and the spots do not develop until the leaves are old. Plate XII shows the symptoms of the disease.

III. Parasitism

Single spore culture of the fungus was obtained by the usual plating method and a series of inoculation experiments were carried out on *tál* plants that were about two to two and a half years' old. The leaves were rubbed gently for five minutes with absorbent cotton immersed in 1 : 1000 solution of mercuric chloride and then the disinfectant was washed off thoroughly with sterile distilled water. Inoculations were made as follows :

(i) By spraying the leaves on the upper and lower surfaces with a suspension of spores from pure culture.

(ii) By placing bits of culture containing the crushed black fruiting bodies of the fungus on the upper and lower surfaces of the leaves.

(iii) By placing bits of agar with the fungus on it on needle pricks made through the upper and lower surfaces of the leaves.

(iv) By spraying with a suspension of spores on needle pricks made through the upper and lower surfaces of the leaves.

On the third day infection was observed on all leaves inoculated through wounds, but no evidence of infection was noted on leaves inoculated without wounds even after 15 to 21 days. Young infections were characterised by yellowish brown spots which were about a millimeter in diameter. The spots were circular to oblong and somewhat shrunken. The lesions gradually increased in length and width. In advanced stages of infection the patches became gray, as in natural infection. The spots turned dark brown. The lesion soon coalesced forming larger irregular areas. The black fruiting bodies appeared on the gray centers of the lesions on the upper surface of the leaves in 7 to 11 days.

A large number of inoculations were made. In every case it was found that the fungus could infect only wounded surfaces of the leaves. From all the infected plants the original fungus was isolated in each case. Controls were kept and they remained healthy throughout the experiments.

Cross inoculation experiments were carried out and it was found that the fungus could infect only wounded leaves of *Areca catechu*, *Cocos nucifera* and *Phoenix sylvestris*.

IV. Morphology

Mycelium.—The mycelium of the fungus extends between the cells of the leaf, throughout the discoloured lesion on the leaf. The hyphæ are exceedingly fine, sparingly septate and colourless.

In pure culture both submerged and aerial hyphæ are produced. When young the submerged mycelium is densely granular, septate, hyaline, vacuolate and somewhat irregular in outline. The cross walls are somewhat hard to distinguish. When old, the granules of the mycelium disappear. The aerial mycelium, when young, is very sparsely granular and hyaline. When old granules seem to be absent from the cells of the mycelium.

Pycnidia.—Underneath the upper leaf epidermis, the hyphæ collect into masses which develop into bowl-shaped, thin walled spore cases, the pycnidia (Fig. 1), the basal wall of which is distinct, while the lateral and top walls are slender and rather obscure. In culture the pycnidia are present in large numbers on the loose mycelium growing on the medium and also on definite stroma composed of interwoven hyphæ. They are of diverse shapes and sizes and may be globose, spherical, rectangular or oval. The pycnidia formed on leaves measure 130 to 420 μ and those on oat agar range from 85 to 240 μ in diameter.

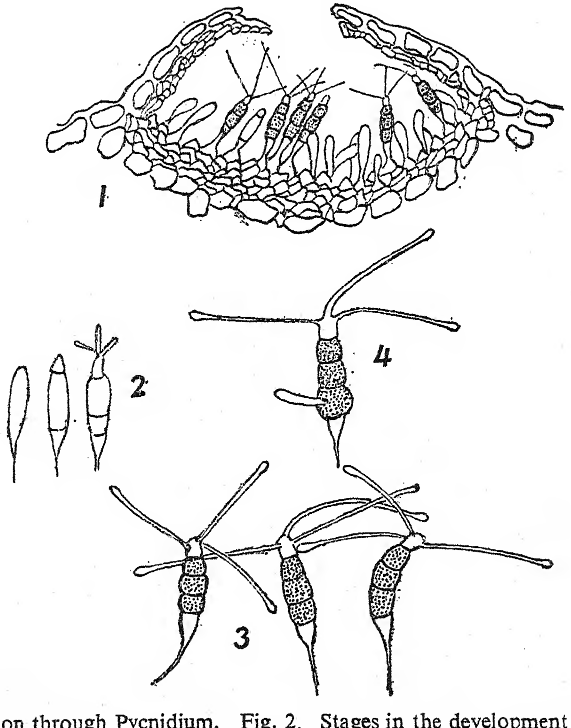


Fig. 1. Section through Pycnidium. Fig. 2. Stages in the development of conidia. Fig. 3. Mature conidia. Fig. 4. Germination of a conidium.
Fig. 1, ×250; Figs. 2–4, ×450.

On the inner wall of the lower half of the pycnidium, a layer of spore-bearing cells occurs. From each of these, a stalk grows out into the cavity of the pycnidium and terminate in a spore. When

ripe, the spores are detached with the stalk, which remains as an appendage at the base of the spore. At the same time, the epidermis and the slender top wall of the pycnidium underlying it become raised up and then ruptured by pressure from below, opening outwards in a crack of irregular shape, through which the spores are liberated in such quantities that they collect in little black crusts round the mouth of the pycnidium. Spores from the pycnidia developed in culture are liberated by a rupture of the wall at the top, or sides to the exterior or at the base into the stroma or culture medium.

Conidia.—The conidia (Figs. 2 and 3) are borne on short hyaline pedicels. They are yellowish to light green when young and turn brown with age. They are spindle-shaped, somewhat curved, tapering at both ends, divided by four septa into a row of five cells, of which the three central are dark coloured while the other two form a kind of colourless cap at each end. From the lower end the persistent stalk on which the spore was borne projects as a slender tail. At the opposite end, the end cell grows out into three, rarely four, colourless thread-like appendages of considerable length; these appendages very possibly help the dissemination of the spores by the wind.

The entire conidium measures from $11\cdot7$ to $28\cdot3\,\mu$ in length and $3\cdot3$ to $6\cdot7\,\mu$ in width on oat meal agar and $14\cdot4$ to $21\cdot6\,\mu$ in length and $4\cdot7$ to $7\cdot2\,\mu$ in width on leaves on the host. The appendages of the spores from oat meal agar vary in length from 4 to $28\cdot3\,\mu$ and on the leaves from $7\cdot2$ to $25\cdot2\,\mu$.

V. Growth in Culture

The fungus was grown on oat meal, corn meal and potato-dextrose agars. About 20 hours after the transfers were made, white, rather coarse mycelial growth was observed on all media. An abundance of growth was noticed on oat meal agar and fairly abundant growth was observed on corn meal agar. On potato-dextrose agar the growth of the fungus was scanty. Generally the growth of the mycelium on all media was at first slow and creeping, then it became faster, until the mycelium was thick. The growth of the hyphæ was both aerial and submerged but on all substrata the aerial growth was more pronounced. Zonation was clear on all media. Two to three zones were noted on the growth of mycelium in 4 to 6 days. As the fungus grew old the growth in the first zone was usually covered with fruiting bodies. The mycelium then lost its fluffy appearance. Owing to the formation of numerous fruiting bodies the surface of the medium and substratum became covered with black, shiny, tar-like slimy masses of sporocarps.

The fruiting bodies are at first silver gray, somewhat resinous specks but later they turn tar black. The spores are produced five days after transfer on corn meal and potato-dextrose agars; on oat meal agar the spores began to form in four days.

VI. Spore Germination

Spores were sown in distilled water and in a 5 per cent. glucose solution in drop cultures for germination study. In both these media the lowest of the three coloured cells was the germ-cell. This cell

swells, becomes nearly round and marked by a light ring round the middle and then puts out a (or rarely two) germ tube from the sides (Fig. 4).

Germination in distilled water was as follows. In $2\frac{1}{2}$ hours few spores showed the germ cell becoming colourless and spherical, and after 4 hours' germ tubes 12 to 50 μ long and 1·5 to 2·5 μ wide were seen protruding from the sides. After 5 hours, one spore had 2 germ tubes coming out close to each other on the same side of the germ cell. After 24 hours, the majority of the spores had germinated, sending out generally one germ-tube which often branched at the base, but occasionally two, one on each side of the germ cell. The germ-tubes were sparingly branched and sparingly septate. In some cases a good number of spores had undergone no change while others had the germ cells spherical and swollen but had not germinated.

In 5 per cent. glucose solution early germ ination was more general and the growth of the germ tubes more luxuriant than in distilled water. After one hour in the culture medium the spores began to show signs of germination. The germ cell loses its colour and becomes spherical and swollen, increasing to about 8 to 9 μ in diameter. In a culture 4 hours' old the majority of the spores had germinated. The germ cell of some spores had swollen to a diameter of nearly 10 μ and had produced generally one germ tube, but sometimes two, one on each side of the germ-cell, non-septate and varying in length from 3 to 15 μ and in width from 2 to 4 μ. In a culture 24 hours' old the germ tubes were of varying length, much branched and septate, varying in width upto 6 μ.

VII. Temperature and Growth

The linear rate of growth of the fungus was studied on oat meal and potato-dextrose agars at various temperatures. The experiment was carried out in selected petri dishes of uniform size into which equal amounts of the medium were poured. All the dishes were inoculated at the same time and kept at various temperatures in darkness. The experiment was run in triplicate and repeated twice. The fungus was found to grow over a wide range of temperatures varying from 15° to 35° C. The fungus, however, grew well between 20° and 30° C. and temperatures above and below were detrimental to the growth of the fungus. It was also noticed that the optimum temperature for growth lies between 25° and 30° C.

VIII. Perpetuation and Dissemination

Intensive studies to determine the mode of perpetuation and dissemination of the parasite have not been undertaken. Limited studies and circumstantial evidence, however, have demonstrated that the parasite lives from one season to another, as mycelium and pycnidia within the tissues of the *tál* leaves. The leaves which dry, and fall off owing to the disease serve as the resting place of the fungus. When conditions are favourable for its development the mycelium produces fruiting bodies the spores of which serve as inocula for primary infection.

In November 1942 pieces of naturally infected leaves were wrapped in tissue paper and carried through the rest of the winter and summer months under the following conditions :

(i) Hung on the tree in open.

(ii) Placed on the surface of the ground.

Isolations were made from these materials in October and November 1943 and the fungus was recovered in every instance. Inoculation experiments were carried out by using these isolations as inocula and in 95 per cent. cases infections were successful.

In the cultivation of *tál* sanitary methods are not at all followed. Diseased old leaves that have fallen are allowed to remain and rot in the ground nearby. Sometimes old leaves are allowed to remain hanging on the plant. In almost all localities one comes across piles of fallen leaves lying about. From these piles a large number of isolations were made during the years 1943 and 1944 beginning from November and ending in October next. In all cases the fungus was recovered. It can thus safely be concluded that the parasite perpetuates in the dead leaves lying near about *tál* plantations.

The parasite may be carried unintentionally by men from one place to another with green or dead leaves. Careful obseravations indicate that the parasite is disseminated through the agency of wind and rain.

IX. Control and Prevention

From these studies it will be evident that the disease can be controlled by systematic collection and destruction by burning of the affected leaves that lie on the ground or remain hanging on the trees and serve as a source of inoculum. Even slightly affected leaves should be severed from the plant and destroyed.

Preventive methods have been carried out with success. Spraying the plants with 2 : 2 : 50 Bordeaux resin-soda mixture at intervals of 15 days taking care to reach the youngest leaves have given promising results. It was found necessary that the spraying be done carefully so that the surface of the sprayed leaves were uniformly and thoroughly covered with the spray fluid.

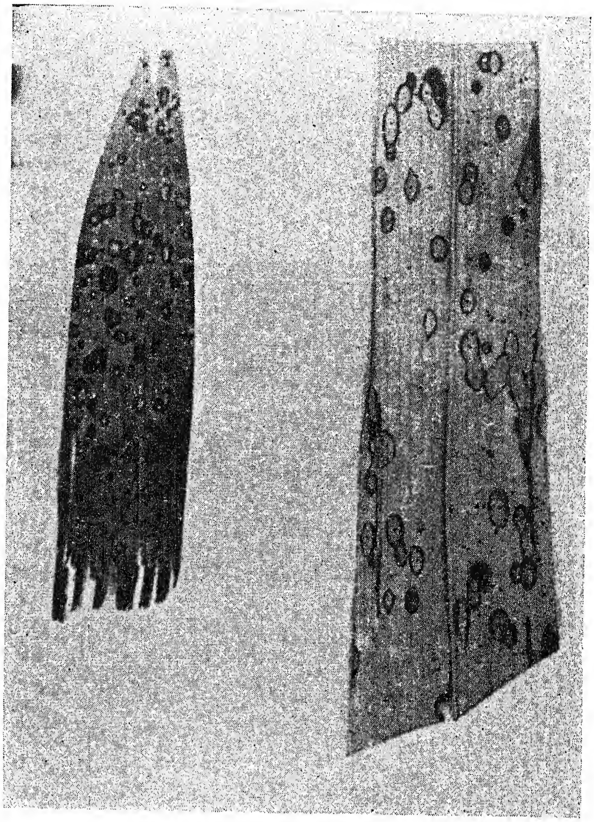
X. Summary

Pestalotia palparum Cke. causes a serious leaf spot of *Borassus flabellifer* in Assam. It impairs the value of the leaves as a material for the manufacture of hand fans and lowers the fruiting capacity of the plant.

Symptoms of the disease have been described.

Inoculation experiments carried out show that the fungus is a wound parasite and can infect only wounded surfaces of leaves. Cross inoculations have shown that the fungus can infect also the wounded leaves of *Areca catechu*, *Cocos nucifera* and *Phoenix sylvestris*.

The morphology of the parasite on the host as well as on culture has been described.



Symptoms of the disease

S. CHOWDHURY—

A LEAF SPOT OF BORASSUS FLABELLIFER *L.*
CAUSED BY PESTALOTIA PALMARUM *CKE.*

Growth on culture and spore germination have been studied and the details described in the text.

The fungus has been found to grow over a wide range of temperature, the optimum for growth lying between 25° and 30° C.

The parasite survives in the affected leaves lying in the ground and is disseminated by wind and rain.

The disease can be controlled by systematic collection and destruction of the affected leaves and prevented by spraying the plants with a Bordeaux resin-soda mixture.

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A NOTE ON THE DEVELOPMENT OF POLLEN OF *MYRISTICA FRAGRANS* VAN HOUTTEN AND THE AFFINITIES OF THE FAMILY MYRISTICACEÆ

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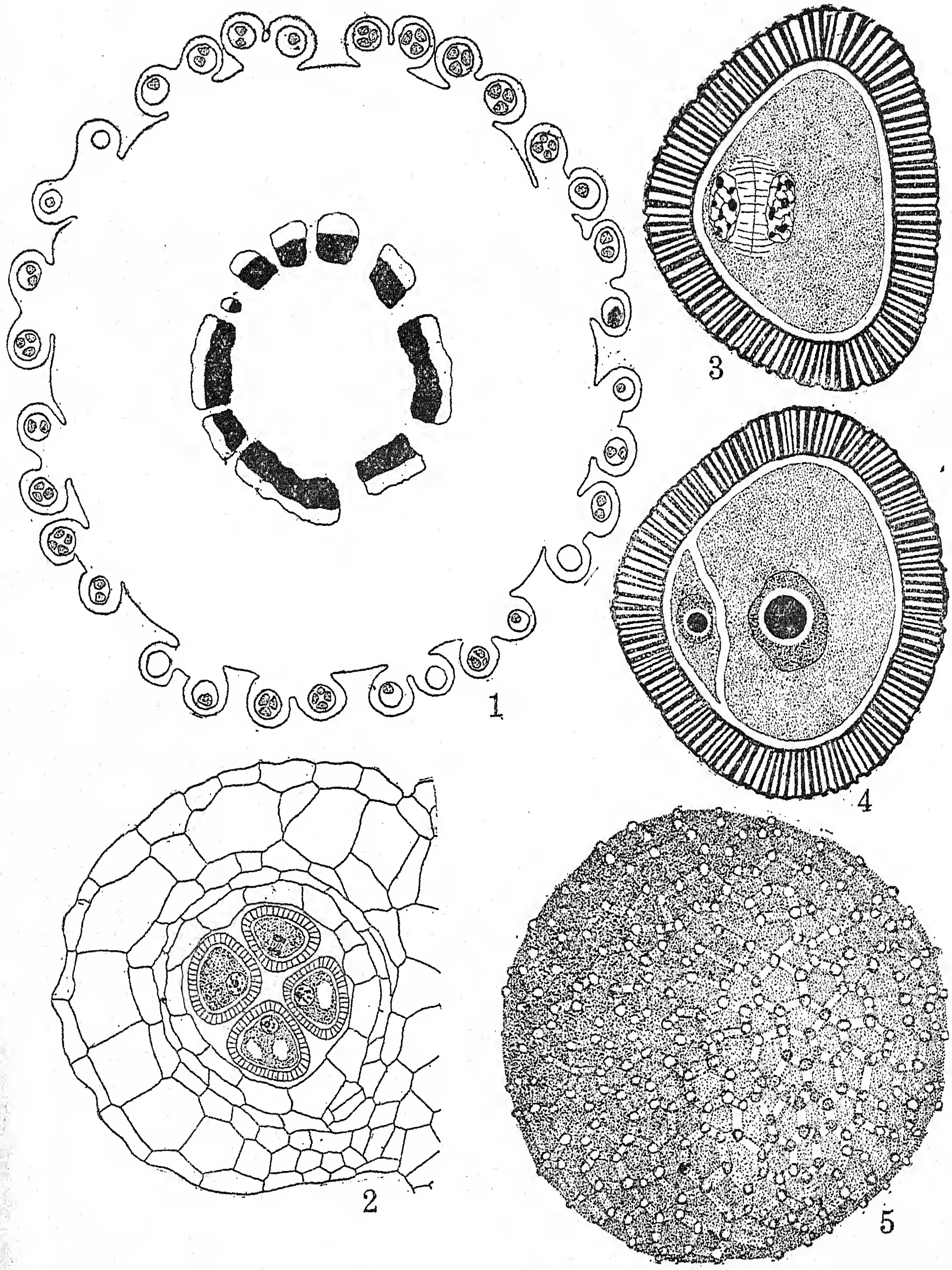
Our knowledge of the embryological characters of the Myristicaceæ is very limited. Voigt (1888) long ago made a few observations on the structure of the ovule and endosperm of *Myristica frag·ans* Van Houtten. He noted that the nucellus is well developed ; the outer integument remains free from the inner right up to the chalaza, while the latter is fused with the nucellus in the lower half ; and the ruminate endosperm probably develops according to the nuclear type. This is, however, the only information we have at present not only about this species but for the whole family Myristicaceæ.

Myristica fragrans is the well known nutmeg tree. The species is a native of the Molucca Islands, but it is now widely cultivated not only in the East Indies and Malay States, but also in Ceylon, West Indies and other tropical countries. The author during a short visit to Ceylon in December 1936 collected some material of the male flowers of this species from a tree growing in the Royal Botanic Garden, Peradenyia. This material did not include all the stages of development, but as nothing is known about the development of pollen and male gametophyte of the Myristicaceæ, it has been considered worthwhile to publish a brief account of the embryological characters that have been observed in this material.

The Male Flower

The male flowers are borne in lax, slender, supra-axillary racemes, 1–2 in. long. They are themselves about $\frac{1}{4}$ in. long, nodding, ellipsoid and bracteolate. The perianth is glabrate, 3-lobed and valvate. It has been shown previously (Joshi, 1943) that this trimerous perianth has been derived from a pentamerous whorl. The number of stamens in a male flower has been described by Hooker (1890) to vary from 9 to 12, but Fig. 1 shows that there are sometimes only 8 stamens. The stamens are connate and form a central cylindrical column. The lower part of this column is differentiated into a stalk-like structure, while the upper part bears anthers. The column is generally believed to have been derived from the fusion of filaments, but even the histological study does not reveal the individuality of the filaments (Fig. 1).



Figs. 1–5. *Myristica fragrans.* Fig. 1. Transverse section of the central column in the anther-bearing part showing the arrangement of the anthers and the vascular bundles. Fig. 2. Transverse section of an anther-lobe after the liberation of the pollen grains from the mother cells showing the structure of the anther wall. Fig. 3. A pollen grain in section showing the first division of the nucleus. Fig. 4. The same showing the formation of the generative cell. Fig. 5. A mature pollen grain in surface view.

Structure and Development of the Pollen

The anther wall consists of 5 layers of cells (Fig. 2), the epidermis, the fibrous endothecium, two middle layers which are crushed in later stages, and the tapetum. The last is of the secretory type. The tapetal cells remain uni-nucleate throughout their life, a condition which is comparatively rare among the angiosperm (see Cooper, 1933). The pollen mother-cells in an anther-lobe are arranged mostly in a single row. This fact remains clear for sometime even after the liberation of the pollen grains from the mother cells. The tetrads are isobilateral. Both in the arrangement of the pollen-mother cells in a single row in each anther-lobe and in the form of the pollen tetrads, *Myristica* agrees with many genera of the Anonaceæ, *e.g.*, *Anona*, *Xylopia* and *Monodora* (*cf.* Schnarf, 1931).

The first division of the pollen grain nucleus has been followed very clearly, particularly with regard to its polarity, as the pollen grains in this species do not round off immediately after their liberation from the mother cells and continue to occupy for sometime the same position that they had at the tetrad stage. The nucleus prior to this division shifts to the inner side and here it divides in a perfectly normal manner. The spindle organised during this division shows no unusual features (Fig. 3), as Hagerup (1938) has described in *Orchis*. The result of the division is the formation of a spindle-shaped generative cell towards the inner side of the pollen grain (Fig. 4) as Wulff and Maheshwari (1938) have already enumerated in *Symplocarpus*, *Xyris*, *Tradescantia*, *Apocyanum*, *Erica*, *Uvularia*, *Narcissus*, *Bulbine*, *Gasteria*, *Aloe* and *Clivia*. According to them, Geitler has reported the same condition also in many other genera of Liliaceous plants. A feature common to many of them is the presence of a single germinal furrow in the mature pollen grains. In this character the pollen grains of *Myristica fragrans* also agree.

The mature pollen grains are 2-nucleate and 2-celled, as Juliano (1935) and Locke (1937) have noted in *Anona* and *Asimina* respectively of the Anonaceæ. In fact, this character appears to be common to the Magnoliales in general (*cf.* Schnarf, 1939). The exine is reticulately marked and finely tuberculate (Fig. 5). Each mesh of the reticulum is usually pentagonal and at each angle of the pentagon there is a small tubercle. There is a single germinal furrow, as Wodehouse (1936) has noted in the Magnoliaceæ.

Discussion

In the last century there was a considerable difference of opinion with regard to the exact systematic position of the Myristicaceæ. Bentham and Hooker (1862–83), for example, placed it under Monochlamydeæ along with Piperaceæ, Chloranthaceæ and Monimiaceæ in the series Micrembryæ. It is evident that such a position is quite unnatural. In recent times, there has been a general agreement among taxonomists in assigning to Myristicaceæ a position in the neighbourhood of Ranunculaceæ, Magnoliaceæ, Anonaceæ, etc., but there are differences in details. Engler and Gilg (1924) place it in the order

Ranales, sub-order Magnoliineæ, which includes families like Menispermaceæ, Magnoliaceæ, Anonaceæ, Lauraceæ, etc. Bessey (1915) also places Myristicaceæ in his order Ranales. Wettstein (1924) includes it in his Reihe Polycarpicæ, which corresponds to the Ranales of the Englerian system. He places it next to the Anonaceæ and states it is related to that family in spite of the differences in floral structure. Hutchinson (1926), who has split the old order Ranales into several orders, places Myristicaceæ along with Monimiaceæ, Lauraceæ, Gamortegaceæ and Hernandiaceæ under Laurales. His Anonales includes only the families Anonaceæ and Eupomatiaceæ. Thus Hutchinson and Wettstein differ in their views about the exact affinities of the Myristicaceæ. While the latter considers it to be most nearly related to the Anonaceæ, the former believes that its nearest allies are to be found among the Lauraceæ.

The present study shows that the development of pollen in *Myristica fragrans* shows greatest resemblance with the Anonaceæ. This along with the presence of the ruminate endosperm appears to favour Wettstein's view about the close relationship of the two families Myristicaceæ and Anonaceæ.

Summary

The tapetum is of the secretory type. The tapetal cells remain uni-nucleate.

The pollen-mother cells in an anther-lobe are arranged in a single row.

The pollen tetrads are isobilateral.

The generative cell is cut off towards the inner side of the pollen grains.

The mature pollen grains are 2-celled and possess a single germinal furrow. The exine is reticulate and minutely tuberculate.

The evidence from microsporogenesis favours the hypothesis that the family Myristicaceæ is most closely related to the Anonaceæ.

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MODE OF INFECTION OF RICE BY *USTILAGINOIDEA VIRENS* (CKE) TAK.

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Introduction

Butler (1913) writes that the fungus *Ustilaginoidea virens* (Cke) Tak. was first described by Cooke in 1878 from Tinnevelly as *Ustilago virens*. He further mentions that Bredfeld studied the cultural behaviour of the fungus and established that it belongs to the genus *Ustilaginoidea* of the Ascomycetes.

In 1941, while examining diseased spikelets in the paddy fields at the Central Agricultural Experiment Station at Dacca, two different types of infected ears were noticed.

Since only a few ears are affected in the diseased plants and very often matured healthy rice grains are found closely associated with diseased ears, the author was encouraged to study the method of infection.

Distribution of the Disease

False smut of rice has been reported from most of the important rice-growing centres of the globe. Butler (1913) writes that it is found throughout India, more specially on the shores of the Bay of Bengal, in Malaya, Java, the Philippine Islands, China, Japan and the United States. Copeland (1924) describes the rice disease caused by *Ustilaginoidea virens* as green smut, and reports that it is always present in the Philippines and sometimes does considerable damage. Of the sixteen rice diseases reported from China, the green smut comes sixth in descending order of importance (Wei, 1934). Wei describes it as green smut instead of false smut. It has also long been reported from Japan, but did not receive much attention as it does not cause any serious loss to the crop. In Louisiana, even when the fungus is abundant, it does not cause even 1 per cent. damage to the crop. In Sumatra the appearance of green smut is taken as an indication of a crop fine in both quantity and quality.

False smut of rice is frequently seen in Bengal. Hedayetullah (1938) reports its appearance in some plots of paddy, *viz*., Chinsura II, Nagra, and Patnai at Chinsura Farm and recommends the destruction of the affected plants for controlling the disease.

Butler and Bisby (1931) report it from Tinnevelly, Assam, Samalkota and Madras. It is also known from Bombay, Bihar and Orissa, but does not appear to have been observed so far in the Central Provinces

and the Punjab.* Bertus† reports that it occurs in Ceylon during the months of January and February. Su (1937) reports its appearance at Hwambi in Burma, and Mundkur (1940) collected it from Afganistan.

Material and Methods

Diseased materials in different stages of infection were examined and collected in 1941 and 1942 from *Aman* paddy (varieties : *Dadkhani, Kalamkati, Indrasail* and *Bhasamanik*) at the Central Agricultural Experiment Station at Dacca. The material was fixed in the field in form-acetic-alcohol. It was treated for varying periods with different concentrations of hydrofluoric acid to remove the silica from the glumes. The optimum concentration and period for hydrofluoric acid treatment were found to be :—(1) 20 c.c. hydrofluoric acid in 50 c.c. of 50 per cent. alcohol, and (2) 15–20 days.

For fixing the sections to the slides, Land's fixative substituting 'gloy' in place of gum arabic was used. The sections were stained in safranin and fast green, and iron-alum hæmatoxylin ; the former gave more satisfactory results.

Diseased materials in different stages of infection collected from the Konkan, Bombay Province, were also examined in 1944.

Symptoms of the Disease

Ustilaginoidea virens occurs as large, velvety green masses which vary from nearly 5 mm. to 8 mm. in diameter and are so conspicuous as to be noticeable from some distance. Spores are borne all over the surface of the infected region. In other respects the host plant appears to be quite normal and frequently attains the normal height of a healthy plant.

When sections of such sclerotial structures are examined it is observed that a compact mass of fungal hyphæ forms a sort of pseudoparenchymatous tissue in the centre. Towards the periphery the hyphæ are more loosely arranged (Plate XIII, Fig. 1) and bear both terminal and lateral spores as previously observed by Butler (1913). Mature spores possess a very rough, granular, greenish brown coating and remain associated with the sporiferous hyphæ forming the outermost layer of the sclerotium. Spores which are somewhat younger and formed next to the outermost surface are almost brown in colour ; the youngest spores situated at the centre of the fungus ball are hyaline.

Nature of Infection

Diseased materials from several sources were examined and two types of infected panicles were observed. In the first type a few sclerotial structures are formed on the panicle in place of grains and most of the glumes of the spikelets are empty. In the second type very few sclerotial structures are found on the panicle and most of the

* Information supplied by Departments of Agriculture of these Provinces.

† Personal communication to Dr. P. Maheshwari.

glumes contain normal rice grains. In such cases some of the glumes containing mature grains are found to be infected with spores of *Ustilaginoidea virens* which remain associated with the hairs of the glume. These spores are fully matured and greenish brown in colour.

When empty glumes of the first type are thoroughly teased and examined it is observed that the anther lobes containing pollen grains as well as the feathery stigmas are infected with fungus mycelium (Plate XIII, Fig. 2). On removing the glumes and separating all parts of the spikelet it is seen that the flowers of rice plants are infected with the fungus at a very early stage before fertilization takes place. When such infected spikelets in different stages of infection are dissected and examined it is observed in every case that the essential organs of the flower, *i.e.*, the andrœcium and gynæcium are buried inside the central core of the pseudo-parenchymatous tissue of the fungus ball. The wall of anther lobes is found to be intact and pollen grains are preserved inside the anther lobes (Plate XIII, Fig. 3). Thus it appears that fertilization never takes place and as a consequence the rice grain is never formed in such cases.

Microtome sections (10 μ thick) of the fungus ball were examined with a view to studying the condition of stamens and the ovary, style and stigmas at a very advanced stage of infection. It seems that the ovary is disintegrated by the fungus, but the style, stigmas and anthers are preserved and buried inside the fungus ball (Plate XIII, Fig. 4). Pollen grains are invariably present inside the anther lobes.

Unlike the first type of infection, in the second type most of the glumes contain normal grains and only very few sclerotial structures are observed. Serial sections of several spikelets were cut to study the nature of infection in this case. In early stages of infection dense clusters of spores are seen along the two lines where the margins of the lemma and palea are interlocked with each other. In sections it appears as if a stream of these spores were proceeding inwards from these points with the purpose of entering into the grain (Plate XIII, Fig. 5). In a slightly later stage of infection the margins of lemma and palea are seen to separate so that some of these spores succeed in making their way through this opening (Plate XIII, Fig. 6). In a still later stage, due to a further gaping apart of the margins of the lemma and palea, a wide passage is formed and a large number of spores enter and come in contact with the pericarp of the fruit (Plate XIII, Fig. 7). Once the spores are there, they germinate and produce the mycelium in a comparatively short time.

The cells of the epidermis and mesocarp were found to be most susceptible to the attack of the fungus. In most cases it was observed that the cells of the epidermis and the mesocarp are disintegrated at a very early stage of infection while the cross-cells and the tube cells (belonging to the inner epidermis) still remain intact. In the next stage the cross-cells are also invaded. It is interesting to note that the inner epidermis formed by the tube cells is comparatively more resistant to the fungus. The moment the mycelium comes in contact with the endosperm its growth becomes greatly accelerated and ultimately

the whole grain is replaced by the fungus. The fungus ball continues to swell and the lemma and palea, the cells of which still remain free from fungus spores or mycelium, are pushed apart still further and thus a much wider gap is formed between their margins, as a result of which large numbers of spores enter into the grain from outside. In a very short time the fungus forms the green velvety mass and spores are formed from the mycelium and thrown out.

Discussion

A very striking feature of the false (or green) smut of rice is that the causal organism makes its appearance only on a few grains in the ear. Sections of stems, leaves and the inflorescence axes bearing diseased ears are seen to be absolutely free from the pathogen. Obviously the infection comes from outside.

From the materials studied so far and the description given above, it is obvious that there are two types of infection. In the first type the flower is invaded at a very early stage in its development which finally results in disintegration of the ovary, while the style, stigmas and the anther lobes containing pollen grains are entirely surrounded by the growing fungus which ultimately gives rise to a sclerotial structure, forming a pseudo-parenchymatous tissue, in the central core of which the style, stigmas and anther lobes are buried and preserved. It is difficult to explain why these parts of the essential organs of the flower are not disintegrated and destroyed by the fungus. In many cases the fungus fails to grow and develop and hence the characteristic fungus balls of green velvety appearance are formed only in a few infected spikelets. Hence in this type of infection fertilization does not take place and the grain is never formed.

In the second type of infection mature rice grains are infected. It appears that the spores are carried by the wind and some of them, by chance, adhere on the hairy surface of the glumes. The lemma and palea being very hard and rigid naturally offer a considerable amount of resistance to the entrance of the spores, and the latter can only enter through the passage between their margins. Spores accumulate in clusters near the marginal regions and the narrow cavity near the margins helps the spores in keeping themselves loosely fixed to the lemma and palea. These spores absorb moisture and swell and exert mechanical pressure due to which the margins of lemma and palea are forced apart forming an opening through which infection takes place. Since only a few grains are affected in the ear, it appears that only in those few cases the spores find their entry into the grain and gradually invade, and finally the whole tissue is replaced by the fungus ball.

Butler (1918) writes "the young ovary is invaded by the parasite at an early stage in its development" and his view closely agrees with the first type of infection described above. Butler (1918) also writes "the centre of the sclerotium is composed of pseudo-parenchyma entirely replacing the tissues of the grain", and this agrees with the second type of infection described in this paper. Hence invasion of young ovary by the parasite is the cause of the first type of infection,

while replacement of the tissues of the grain by the sclerotial structure is the result of the second type of infection.

Due to vigorous growth of the mycelium, the glumes are gradually pushed apart and a comparatively large space is formed near the margins of the glumes. The mycelium along with the spores protrudes out through these gaps, and finally the whole infected grain appears like a sclerotium which grows and bursts out between the two closely applied glumes. In a section of a fully infected grain, it is difficult to find out the two glumes which are very insignificant in size as compared to the size of the fungus ball (Plate XIII, Fig. 1).

Summary

The symptoms of the false smut disease of rice caused by *Ustilaginoidea virens* (Cke) Tak. are described.

Two types of infection of the spikelets have been observed. In the first type, due to early infection of the flower, fertilization does not take place and the grain is never formed. In the second type the mature rice grain is infected by germinating spores of *Ustilaginoidea virens* and the grain is finally replaced by the fungus ball.

Acknowledgments

This work was done at the University of Dacca and the author is grateful to Dr. P. Maheshwari for giving facilities to work in his laboratory. The author is indebted to Dr. S. P. Capoor and Dr. G. Watts Padwick for their valuable suggestions. Grateful acknowledgment is also due to Dr. B. N. Uppal for his helpful criticism and for kindly going through the manuscript.

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EXPLANATION OF THE PLATE

Fig. 1. One half of *t.s.* of a fully infected spikelet; *g*, glume; *an*, *t.s.* of anther; *h*, loosely arranged hyphæ towards the periphery (×83).

Fig. 2. Anther containing pollen grains and feathery stigma infected with mycelium of *Ustilaginoidea virens* (×120).

Fig. 3. *t.s.* of an infected spikelet showing an anther containing pollen grains embedded in the pseudo-parenchymatous tissue of the fungus ball (×300).

Fig. 4. Section of a fully infected spikelet showing: *st.* style; *fs.* feathery stigma; *an*, *t.s.* and *l.s.* of anther embedded in the pseudo-parenchymatous tissue (×83).

Fig. 5. Spores of *U. virens* proceeding towards the regions where margins of the glumes are interlocked with each other (×249).

Fig. 6. Margins of the glumes gaping apart and some of the spores succeed in entering through the opening (×249).

Fig. 7. Spores in direct contact with the pericarp of the fruit; *sp*, cluster of spores; *p*, pericarp (×300).

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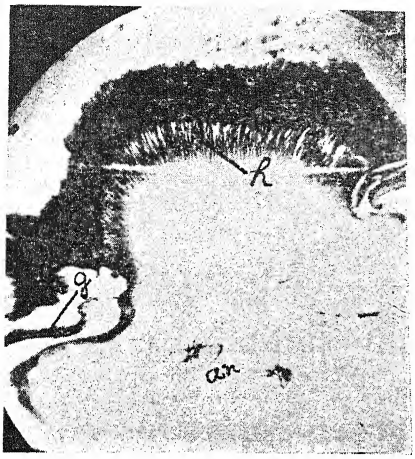

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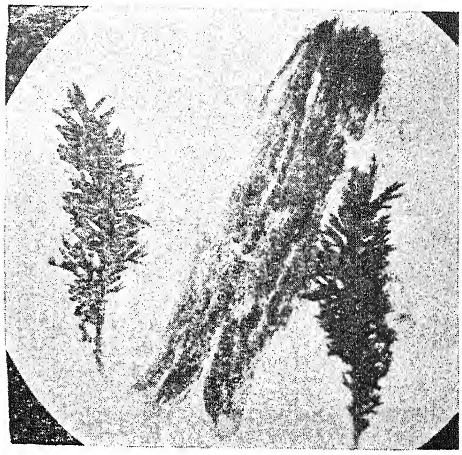

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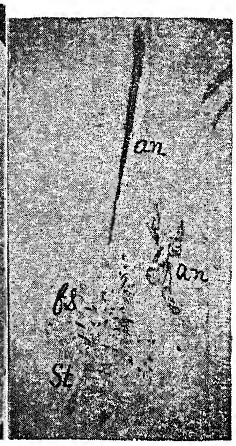

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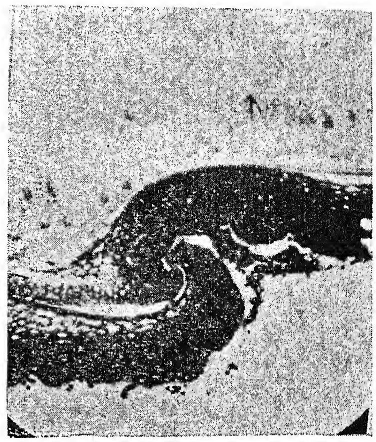

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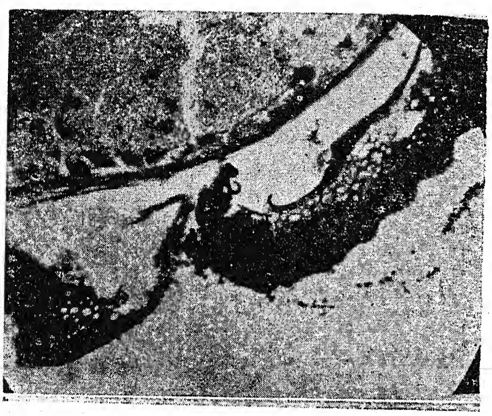

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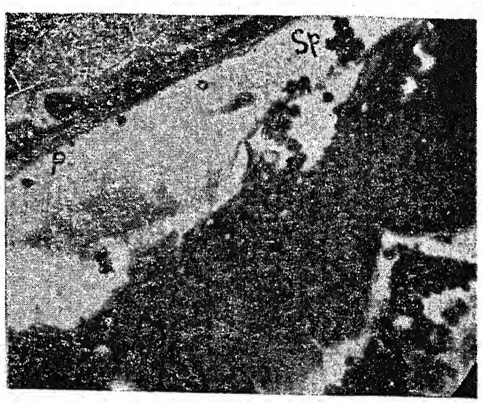

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S. P. RAYCHAUDHURI—

MODE OF INFECTION OF RICE BY USTILAGINOIDEA VIRENS *(CKE.) TAK.*

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REVERSIBLE CHANGES IN THE WEIGHT OF A PLANT

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In his paper on the autonomic movements of leaves (Krishna Iyengar, 1942 *a*) the author pointed out that the leaf movement signifies though indirectly the fluctuating water-content of the plant-body. Since there was appreciable magnitude about the leaf's oscillatory movements, the author expected significant changes from time to time in the water-content of the plant-body also. It was this idea which is responsible for the present investigation. A note on these changes in *Lycopersicum esculentum* was published sometime ago (Krishna Iyengar, 1943 *a*). Since then an exhaustive study of the linear changes in the living plant tissues has also been made by the author (Krishna Iyengar, 1946), an abstract of which was communicated to the Indian Science Congress Session of 1945. Here also the changes were reversible and rhythmic, signifying the periodic variation in the water-content even at short intervals of a few seconds, thus confirming the author's present observations. The reversible changes in the weight of a plant, the probable working principle and significance are explained below.

Materials and Methods

Young potted plants of *Bryophyllum trifoliatus*, *Dolichos lablab*, *Lycopersicum esculentum*, *Mimosa pudica* and many others, and *Musa* sp. under field conditions were studied, although only a few are described in this paper. The potted plants were carefully removed from their pots and their root system gently though thoroughly washed, taking all precautions against any damage, before using them for experiments. In each case, solution was prepared from the soil in which the plant was growing and this was filtered and thoroughly aerated before use. The plant was weighed with minimum delay, and then it was counterpoised on the balance with the root-system suspended in the solution kept in a wide trough, which was free from the balance by a bridge arrangement over the pan. A lever capable of magnifying

about 15 times was made use of to observe the small changes in weight. Readings were taken at intervals of 10 or 15 minutes and the graphs were drawn from these. In only a few experiments recording was at intervals of 10 seconds and the magnification was about 600 to enable the study at very short time-intervals. In some cases the graphs have been slightly magnified to enable a better reproduction of the same after reduction. A few plants have been studied to trace the relationship between the direction of leaf-movement and the reversible changes in weight. In *Musa* a leaf which was neither too young nor too old was selected. Even here only the middle part of the leaf where the width was almost uniform was selected. From this region segments were detached at intervals of an hour, and disks, one centimeter in diameter, were cut with the help of a leaf-cutter. At a time 15 or 30 disks were cut and these were immediately weighed. From the data thus obtained graphs were drawn. Since the leaf is large it is possible to study the weight-fluctuations over a period of 24 hours or more from a single leaf with all the attendant advantages. Dry weight was also determined to have an idea of the percentage of water-content fluctuation.

Experiments were performed not only in diffuse natural light but also under artificial illumination. At times the observations were

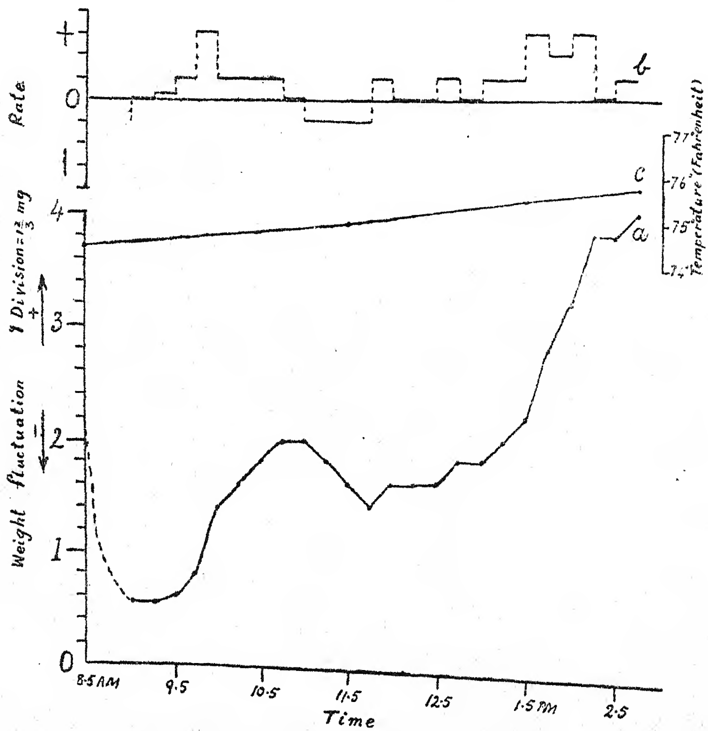

Fig. 1. Graphs to show (*a*) fluctuation in the weight of a young plant of *Bryophyllum trifoliatus*, (*b*) its rate, and (*c*) room temperature.

made from morning till evening and at other times for days together at a stretch to make sure that these changes formed an inherent normal feature of daily occurrence. The observations are as follows :—

OBSERVATIONS

Bryophyllum trifoliatus (Fig. 1).—The changes in weight were recorded at intervals of 15 minutes under artificial illumination. The figure shows the reversible changes in weight. Here (*a*) indicates the oscillation in weight, the peaks and troughs showing the gain and loss in weight respectively. The rate of variation in weight on the *plus* or *minus* side is represented in (*b*) ; temperature variation during the period of investigation is represented in (*c*). The sigmoid curves are noticed in the weight fluctuations. The weight of the plant on the previous day at 7 p.m. (advanced time) was 2·305 grms. At 7·30 a.m. on the following day it was 2·460 grms. From 9 a.m., after fluctuations in weight, the plant as per record shows an increase of 40 mgm. Still it weighed only 2·43 grms., being thus ·03 grm. less, making one infer that between 7·30 and 9 a.m. the plant must have lost ·07 grm. This also shows that the plant shows significant increase in weight during the evening hours and night.

Dolichos Lablab (Figs. 2 and 3).—Fig. 2 shows the activity of a seedling about 6 days old. The readings were taken at intervals of 10 minutes, the plant being studied under artificial illumination for a period of about 7 hours from 10 a.m. At 10 a.m. the plant weighed ·920 grm. The plant showed a tendency to increase in weight when recording was started, but this was followed by a fall at 11 a.m. (*a*). Even here the increase in weight is sigmoid. The weight of the plant at 5 p.m. was 1·025 grms. Since there was only slight increase in weight till 2 p.m. it can be inferred that during the afternoon hours the increase was more significant than during the morning hours. Just

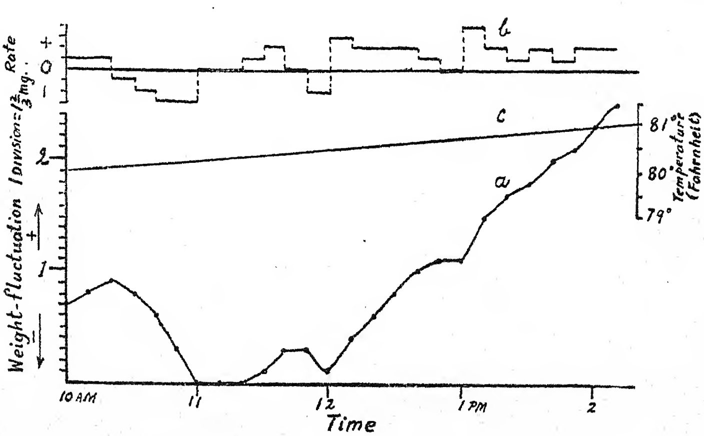

Fig. 2. Graphs to show (*a*) fluctuation in the weight of a seedling of *Dolichos Lablab*, (*b*) its rate, and (*c*) room temperature.

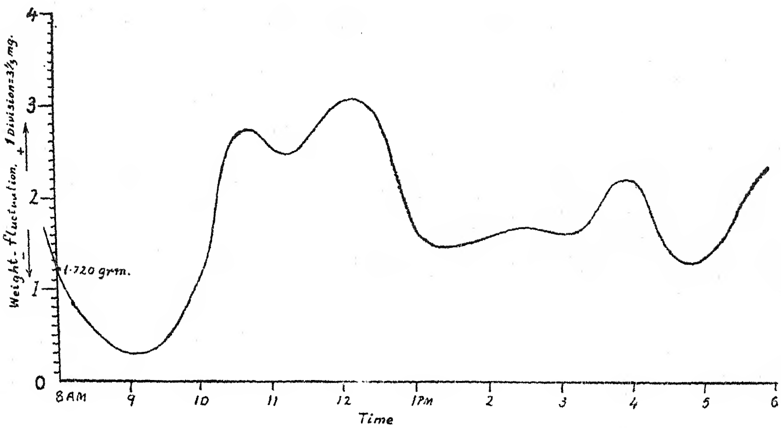

Fig. 3. Diurnal changes in the weight of a slightly older seedling of *Dolichos lablab*. (Graph slightly smoothened).

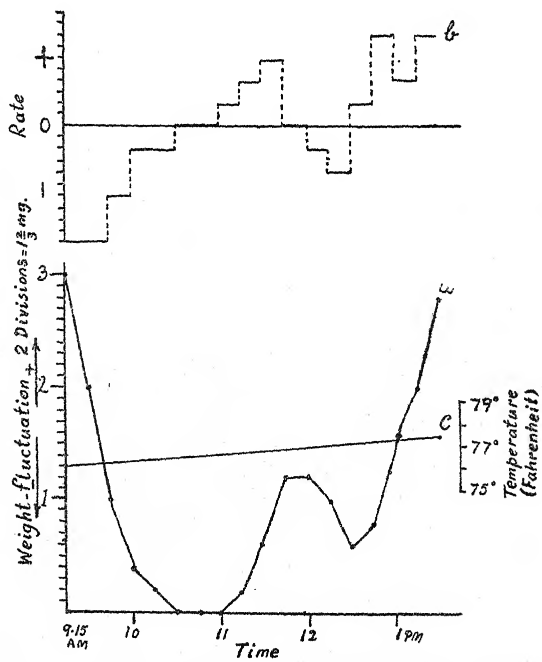

Fig. 4. Graphs to show (*a*) fluctuation in the weight of a young *Lycopersicum* plant, (*b*) its rate, and (*c*) room temperature.

as in the previous case rate of fluctuation in weight and temperature changes have been represented in (*b*) and (*c*) respectively.

In addition to this, experiments were conducted on slightly older plants (about 10 days old), the plants being studied for a period of 4

days or more under natural light, though diffuse, to study the daily rhythm (Fig. 3). These oscillations in weight seem to be rhythmic in their nature and part of the daily routine of a plant.

An effort has been made to estimate the magnitude of fluctuation in weight. There was a difference of nearly 100 mgms. between the maximum and minimum weights when the maximum weight for the day was nearly 1·730 grms. thus signifying a variation of about 6 per cent. on the wet weight. A rough estimate of the dry weight of the plant indicated a water-content of nearly 75 per cent. this suggesting a water-content variation of nearly 8 per cent. with all the possible effects on the other activities.

Lycopersicum esculentum (Figs. 4, 5 and 6).—The oscillatory changes in the weight at intervals of 15 minutes have been recorded in Fig. 4 (*a*). At 9·15 a.m. when the recording was started the plant was losing weight. By about 10·30 a.m. the plant had lost maximum weight. From 11 a.m. the plant began to increase in weight. The

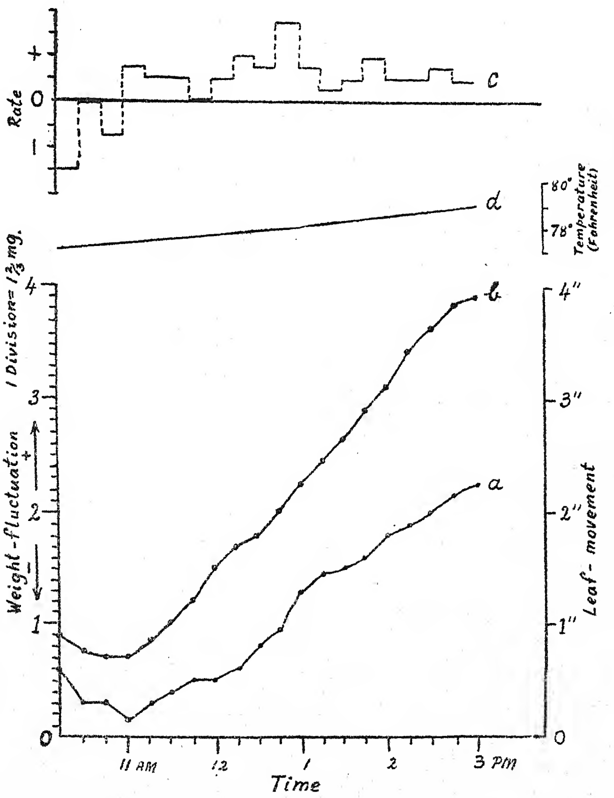

Fig. 5. Graphs to show (*a*) fluctuation in the weight of a slightly older *Lycopersicum* plant, (*b*) leaf-movement, (*c*) rate of change in weight, and (*d*) room temperature.

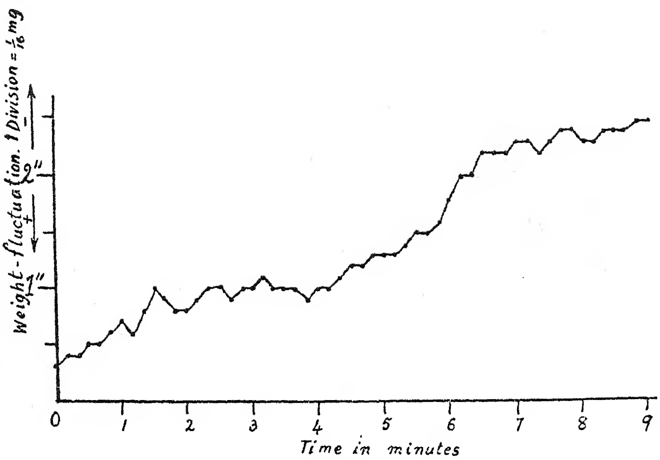

Fig. 6. Finer oscillations in the weight of *Lycopersicum* plant.

trough in the graph noticed at 12·30 p.m. is followed by a sharp rise in the weight ; and this was kept up till the end of the experiment, and till evening. Just as in the previous cases (*b*) represents the rate of change in weight and (*c*) denotes the temperature changes. A similar feature is noticed in Fig. 5 although with slight time variation. In this case the plant was studied under natural light, while in the previous case the light was artificial. An attempt is made to study the relationship between the weight fluctuations (*a*) and the leaf-movement (*b*). The two are recorded from different plants of about the same age and exposed to identical conditions. The agreement between the two is significant. The rate of fluctuation in weight is denoted by (*c*). Further observations on this aspect were made at intervals of 10 seconds under artificial illumination employing a magnification of about 600. Instead of the ordinary lever, the optical lever designed by the author (Krishna Iyengar, 1942 *a*) was made use of. Fig. 6 explains the results of these observations. Two points are noticed here, these being (1) that the weight-fluctuation is sigmoid even during short time-intervals and (2) that each sigmoid curve taking a few minutes includes fine oscillations, occurring at intervals of about a minute. Since the plant was losing weight at the time of observation it is clear that these oscillations denote minute changes in weight on the *plus* side even though the plant was, in general, losing weight. On account of practical difficulties it was not possible to record at intervals shorter than 10 seconds.

Mimosa pudica (Fig. 7).—Even here the author has tried to trace the relationship between the leaf-movement (*b*) and changes in weight (*a*). The two aspects were recorded from the same plant, the leaf-movement being studied on one day and the oscillations in the weight on the following day, the conditions being almost identical. The agreement between the two seems to be striking. The other curves are those of rate of changes in weight (*c*) and temperature (*d*).

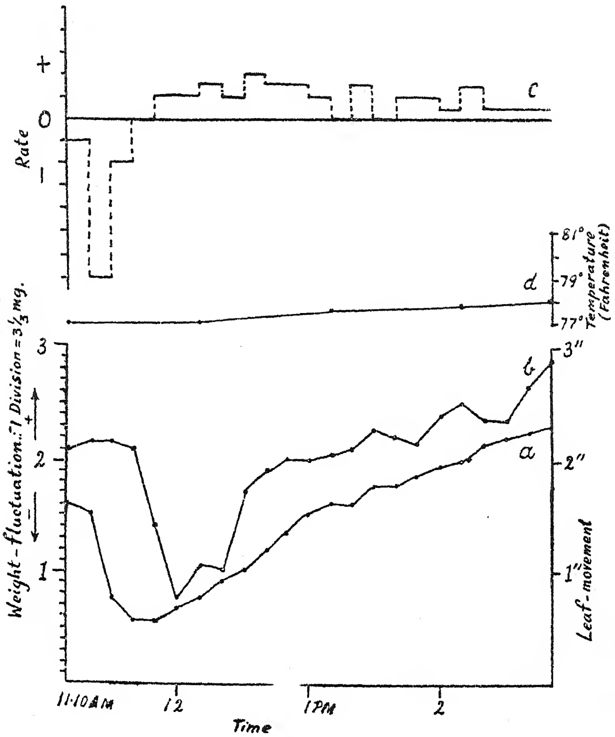

Fig. 7. Graphs to show (*a*) fluctuation in the weight of *Mimosa pudica* plant, (*b*) leaf-movement, (*c*) rate of change in weight, and (*d*) room temperature.

Musa sp. (Fig. 8).—The plant was studied under field conditions. In this case as has already been mentioned disks were cut at intervals of an hour and immediately weighed. From 6 a.m. till late in the night this was followed on a clear day and the graph drawn from the data thus obtained. In certain respects this graph is better than the others since the observations are from the early hours of the morning. A careful study has revealed that the disks collected generally showed a fall in weight between 6 and 11 a.m. with slight variation in time from day to day. This is followed by an increase in weight till about 1 p.m. There was a second fall in weight after this, although this was not generally as significant as the change during the early hours of the morning. After 2 to 2–30 p.m. there was a tendency to increase in weight during the hours of the evening and night. The weight at about 11 p.m. and the same at about 6 a.m. did not differ much. An effort has been made to estimate the water-content of the disks to have an idea of the magnitude of change in the water-content. The water-content was 75–78 per cent. during the hours of the night and early morning hours. A variation of about 15 per cent. in weight of the disks during these hours of the day seems to be a possibility in an active leaf. Since these changes

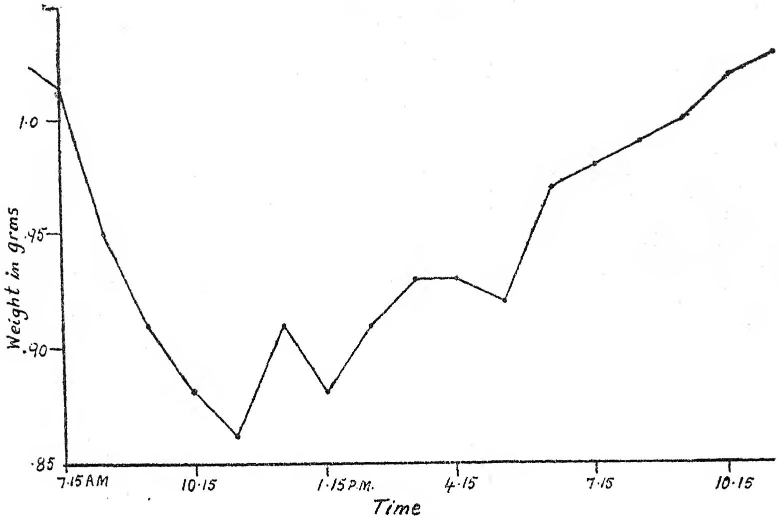

Fig. 8. Weight-changes in the disks of *Musa* leaf at intervals of an hour.

are mostly due to the changes in water-content it may be inferred that the percentage of variation is likely to be more than the figure given above if calculation is made on only the water-content of the selected material.

Conclusion

The following points of interest may be mentioned from the above observations. The plant although it is increasing in weight from day to day, still shows the oscillatory changes in it not only at long intervals of an hour or more but also at very short intervals of even less than a minute. This feature seems to be one of general occurrence in view of the fact that not only plants under field conditions but also plants under laboratory conditions have yielded similar results. It was also noticed that plants either too young or too old are least suited for observations since there are high growth-changes in one and the approaching senility in the other. A similar situation is noticed by the author during his work on the leaf-movements and tissue study. The manifestation of these oscillations seems to be an inherent trait of a plant, although the time, magnitude, duration and frequency may vary with the changes in the conditions, thus indicating the existence of a rhythm about the weight-changes of a plant. The author has already explained the relationship between the direction of leaf-movement and changes in weight, pointing out how the former signifies though indirectly the *minus* or *plus* aspect of the water-content.

Mention has already been made regarding the fine oscillations in weight at intervals of a minute or even less. The oscillations noticed in the leaf-movement and in the linear changes of tissues signifying directly variation in turgidity indirectly denote the reversible changes

in water-content at short and long time-intervals, thus confirming the present observations.

The daily variation in the water-content can be better understood by a glance at the diagram represented below (Fig. 9). There may be variation in the magnitude, duration and frequency of the oscillations but the daily rhythm is always there. Since the tissues manifest this feature even when transpiration and photo-synthesis are not there it may be inferred that these changes are inherent in their nature and connected in a way with the periodic changes in the metabolic processes of a plant. It looks as if the *plus* aspect of water-content is as necessary as the *minus* aspect of the same in the daily life of a plant. While it is

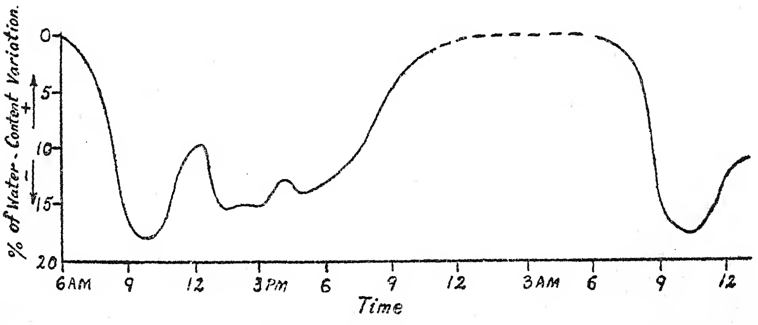

Fig. 9. Diagrammatic representation of the daily rhythm and the water-content variation in plant (*from* the author's observations on *Musa* leaf).

possible to account for the loss of weight in the early afternoon hours it cannot be stated that high temperature or increased illumination was responsible for the rapid loss of water during the early hours of morning since conditions are least favourable for a high rate of transpiration. This makes one feel that there is a visible effort on the part of the plant to get rid of that extra water it had retained till the early morning hours for some other activity. A similar explanation can be given to the loss of water in the afternoon hours, since even under contrôlled conditions this is noticed. It is already an established fact that early morning hours are associated with a high rate of growth while the warm afternoon hours and mitosis generally go together (Miller, 1931). Since the two activities form part of the daily rhythm it looks quite natural that the plant reduces or increases the water-content of its body according to the needs of the period. Thus certain hours are quite favourable for increase in weight while others are favourable for loss in weight.

The rapidity with which one aspect changes to the other is quite striking, and the main factor concerned with this probably happens to be pH variation. The role of pH has been explained by Darwin (1898), Lloyd (1908), Loftfield (1921) and others in connection with stomatal rhythm. Its influence on the permeability has already been emphasised by many. It is quite likely that the daily rhythm noticed in the water-content is intimately associated with the fluctuating pH

of the plant suggesting thereby that even pH is equally open to fluctuation from time to time. Sayre (1926) reports that the contents of the guard cells were acidic when the stomata were closed and alkaline when they were wide open signifying thereby that gain in water-content is associated with the higher pH and the loss with lower pH.

The significant influence of the varying water-content on the several activities of plant has been explained by the author in his papers on respiration and growth (Krishna Iyengar, 1943 *b* and 1944 *b*). It is quite possible that the rhythmic variation in the rates of several activities noticed by the author (Krishna Iyengar, 1942 *a* and *b*, 1943 *a* and *b*, 1944 and 1945 *b*) and directly influenced by varying water-content of the plant-body is ultimately traceable to the constantly changing tone of the living matter.

Time factor seems to be of great significance in all investigations of plant's activities. Since there are significant oscillatory changes in the water-content (as also probably in pH) from time to time it will be necessary in all qualitative and quantitative work to record the time of the day when the estimation is made. In the light of this it follows that all previous work on the estimation of dry weight and water-content percentage is faulty in its approach since the daily rhythm is not taken into account. Similarly in all experiments to determine the osmotic pressure of a cell time-factor should be taken into account since the daily rhythm signifies the possibility of getting different values during different hours of the day. Thus the daily rhythm plays a vital role in all activities of a plant, pH probably being the mechanism employed by the protoplasm to regulate their intensity.

SUMMARY

Potted plants of *Bryophyllum trifoliatus*, *Dolichos Lablab*, *Lycopersicum esculentum* and *Mimosa pudica* and *Musa* sp. under field conditions were studied.

Except in the case of *Musa* where recording was at intervals of an hour in all others weight-changes were recorded at intervals of 10–15 minutes, the plants being studied under natural and artificial light. In *Lycopersicum* the readings were also taken at intervals of 10 seconds.

Reversible changes in weight were noticed in all the plants, these following a certain daily rhythm.

A careful study has revealed the existence of a relationship between the direction of leaf-movement and changes in weight.

Dry weight analysis has shown that these oscillatory changes are mostly due to the changing water-content of the plants, the variation in some plants being as high as about 20 per cent. during the hours of the day.

Although the plant is increasing in weight from day to day still the *plus* and *minus* aspects alternate during the hours of the day. These oscillatory changes are probably connected with the changes in the metabolic needs from time to time.

Daily rhythm should be taken into account in the quantitiative analysis of a plant as well as in the determination of the osmotic pressure of a living cell.

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STUDIES IN THE USTILAGINALES

I. The mode of infection of the Bajra Plant (*Pennisetum typhoides* Stapf.) by the smut *Tolyposporium Penicillariae* Bref.

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Introduction

The smut of *bajra* (*Pennisetum typhoides* Stapf.) is one of the commonest and widespread disease in India. It has been found to occur in the various parts of the Bombay and the Madras Presidencies, the Central Provinces, the Punjab and the United Provinces. Its occurrence outside India is not definitely known. Busse (1904) collected a sister species, *Tolyposporium filiferum* Busse, cause of the long smut of Sorghum, from East Africa; Thomas (1921) recorded it from Mesopotamia and Briton-Jones (1922) from Egypt. Yen (1938) and Zundel (1938) record the occurrence of *T. Penicillariæ* on *P. typhoides* and *Penicillaria spicata* Willd., respectively from Africa and the adjacent territories. Mc Alpine (1910) reports various species of *Tolyposporium* from Australia, but so far as the author is aware the occurrence of this species (*Tolyposporium Penicillariæ* Bref.) is not recorded from anywhere else.

According to Ajrekar and Likhite (1933) the smut disease of *bajra* causes appreciable damage during wet seasons. In the United Provinces the disease is quite prevalent. Almost every field visited by the author during the month of September shows infection of grains ranging from a few to almost all in an ear. Similar losses are known to occur in other provinces of India.

To devise successful measures for controlling the disease, however, it is necessary to have an accurate knowledge of the life-history, mode of transmission, and the methods of infection together with its subsequent spread. It is known that in certain smuts like *Tilletia Tritici*, *Ustilago Zeæ* and *Ustilago Heufleri* (Sartoris, 1924), the sporidia and the chlamydospores alone are able to cause infection whereas the mycelium from culture and the secondary spores fail to establish themselves in the host.

Kamat (1933) and Kulkarni (1918) described a few facts about the factors affecting the germination of *Tolyposporium filiferum*. Ajrekar (1931) suggested a few media for the successful germination of the sporeballs of *Tolyposporium Penicillariæ*. The author (unpublished) has worked out in detail the various factors affecting the germination of the sporeballs of the present smut, having a direct bearing on the mode of infection. Ajrekar and Likhite (1933) give an indication to the possible mode of infection. The present study was undertaken to elucidate the life-history of the fungus together with

its mode of infection. The results also include some of the observations on the initiation and the subsequent spread of the disease, the extent of damage due to continued cultivation of the crop during successive years.

Material and Methods

The sporeballs of *Tolyposporium Penicillariæ*, used for the present investigations, were obtained from the diseased ears of *bajra* (*Pennisetum typhoides*), collected during the months of October and November 1940 and 1941, from the neighbouring fields of Lucknow. In all experiments material of the previous season was used. This was preserved dry in contact with the host at the room temperature. *Bajra* plants commonly grown in Lucknow were utilised for the work. The seeds were obtained from totally healthy plants in the field about the harvest time and stored under proper conditions in the laboratory.

The experiments were carried out both in the field as well as in pots filled with ordinary garden soil. The seeds prior to being used were surface sterilised in a solution of 0·1% mercuric chloride for 5 minutes or in a solution of 5% copper sulphate for 20 minutes ; and sown in 2 cm. dibbles at a distance of 9″ in the field and 4″ in the pots at the beginning of the rains. Two seeds were introduced in each dibble and after they had germinated, one of the two seedlings was pulled out. The other was left behind in its original position.

The spore-mass was taken out from the unruptured sori of the previous season, after having been surface sterilised in 10% silver nitrate for 5 minutes and subsequent thorough washings in 3% sodium chloride and sterile distilled water for 5 minutes each.

The ears were covered with butter-paper bags from the time they were wholly enclosed within the sheathing leaf to guard them against infection through the flower.

Different methods were employed for the study of seedling, shoot, localised and floral infections and have been given in the text at their respective places.

The investigations were carried out with a view to ascertain the ability of the fungus to penetrate or invade the tissue of the host plant. The penetration of the hyphæ into the host plant (root, hypocotyl, shoot and flower) was studied by (*a*) maceration method using a mixture of potassium chlorate and nitric acid or in bromothymol blue (Garret, 1937), and (*b*) microtome sections, 10–15 μ thick. The infected samples were fixed in formalin-acetic alcohol or in Navaschin's fixing fluid, the latter being more suitable for cytological studies. The preparations were stained with Fleming's triple stain or with Heidenhain's hæmatoxylin. The latter were destained with picric acid, and were sometimes counterstained with Orange 'G'.

Seedling Infection

Infection through the seedling and especially through the region of the hypocotyl is quite common among the smuts. It was demonstrated by Wolff (1873), Kuehn (1858) and Brefeld (1890) in *Ustilago*

avenæ and Kuehn (1858) in *Tilletia Tritici.* Kulkarni (1918) showed that in *Sphacelotheca sorghi* the entry is affected through the epidermal cells of the shoot below the soil. Ling (1940) reported the penetration of a binucleate hypha directly through the epidermal cell wall of the rye coleoptile by *Urocystis occulta.* Experiments were, therefore, devised to determine the ability of the spores of *Tolyposporium Penicillariæ* to infect the *bajra* plant through the seedlings. Two aspects of spore association were taken into consideration.

(*a*) *Spores in association with the seeds.*—

(i) Surface sterilised seeds were thoroughly mixed with a large quantity of sporemass. These were sown in conical flasks with the malt-agar medium (malt extract 2·5% and agar 2%) and kept at the room temperature. The first sample of 90 seedlings was taken after the first 24 hours when in most of the cases the radicle and the plumule had appeared. Further examinations were undertaken after every 24 hours. In each case a certain number of seedlings were examined by cutting microtome and hand sections, whereas others were transferred to pots for observations as to the appearance of smutted grains in full-grown plants. Proper controls were also kept.

(ii) In a second set of the same experiment, heavily spore-coated seeds were sown in test-tubes with the malt-agar medium. The tubes were incubated in the light chamber at 30° C. (Bhatt, unpublished) for a period of 15 days, thus allowing association of fully germinated spores with the seedlings for that period. After the incubation period the seedlings were simultaneously transferred to pots. The seedlings showed normal growth at the earlier stages but later exhibited etiolation of the leaves and parts of the stem with the result that on transfer to pots, very few of the seedlings survived.

Similar experiment was repeated in pots also.

(iii) Test tubes with the malt-agar medium were divided into two lots. In one lot surface sterilised seeds were sown, while spores were sown in the other. Every 24 hours, for twelve days, spores were introduced in a fixed number of tubes (of the first lot) containing the seedlings, thus providing opportunity for the spores to attack seedlings of different stages of growth. Similarly ungerminated seeds were introduced into a fixed number of tubes of the second lot every twenty-four hours containing spores showing different degrees of germination. The seeds and seedlings as soon as they appeared were, thus, subjected to invasion by the mycelium of different age. The seedlings and the spores were allowed to remain associated together for 15 days. The seedlings were examined only for the penetration of the hyphæ by maceration as well as in sections. None of these showed any trace of the mycelium entering or establishing itself inside the host.

(*b*) *Spores in association with soil.*—

In order to find out if the *bajra* seedlings are directly infected by spores present in the soil, 20 petri dishes were filled with sterilised garden soil inoculated with *Tolyposporium* sporeballs and ten others served as control. Later on in all these plates *bajra* seeds were planted.

On the 4th day, germination of spores was observed in the superficial layers of the soil of inoculated plates. The seedlings were kept in association with the sporeballs for about two weeks after which they were transplanted into pots containing the garden soil. Further, to ensure the presence of spores, sporeballs of *Tolyposporium Penicillariæ* were also sprinkled over the general soil surface of the pots. When the plants had grown up the ears were covered with butter-paper bags to guard against floral infection.

The results of the above experiments were negative in all cases, thereby conclusively establishing that under normal conditions the *bajra* plant cannot be infected through the seedling and that the seed does in no way act as a carrier in the initiation of the disease.

Localised Infection

Brefeld (1890) successfully caused localised infection of the shoot, leaves and flowers in the American corn by the sprouting conidia of *Ustilago Maydis* and came to the conclusion that only those parts of the plants become smutty which have been directly infected, all the rest remaining healthy. Attempts were, therefore, made to ascertain the possibility of localised infection of the *bajra* plant by the smut under investigation.

The various parts—hypocotyl, growing part of seedlings and the base of the floral spike—were infected by two methods: (i) injection of a concentrated spore suspension by means of a hypodermic syringe and (ii) application of spores on superficial wounds.

The results showed that whereas the injection of a concentrated spore suspension in the hypocotyl region, and the application of spores on the superficial wounds on growing points did not cause any infection, the injection at the base of the floral spike produced three diseased ears (one with one sorus, one with two sori, and one with 15), out of a total of 50, the controls being free.

The results of the above experiments clearly indicated that even though the pathogen is provided with optimum conditions for its germination, it fails to initiate localised infection in the various parts of the *bajra* plant.

Shoot Infection

Hecke (1907) used a special technique for bringing about infection in the perennial plants of *Lychnis alba* which he termed as 'shoot infection'. It consists in cutting the new shoot and covering the cut end with spore dust and manure infested with spores, and observing the condition of the flowering shoot. A similar experiment was conducted with *bajra* plants with a slight modification. Early sown *bajra* plants with two aerial shoots were taken. One shoot was treated by the above method, whereas the other was left uncut. The uncut shoot has been termed as primary and the branches coming out from the cut shoots as secondary. The control sets were also similarly treated except that the cut end was covered with soil free from spores of *T. Penicillariæ*. The results are given in Table I.

TABLE I

The effect of 'shoot infection' on the bajra plant by Hecke's method

Type	Total No. of ears	No. of healthy ears	No. of diseased ears
Experimental—			
Primary* ..	30	27	3
Secondary† ..	19	17	2
Control—			
Primary ..	22	20	2
Secondary ..	15	14	1

* Uncut shoot † Cut shoot

It will be seen that the cut as well as the uncut shoots of the experimental and the control sets give more or less similar results. The mycelium from the spores does not seem to affect either the primary or the secondary branches indicating that the mycelium does not travel down the stubble into the primary shoot nor upwards in the secondary shoot.

FLORAL INFECTION

Maddox as early as 1897 demonstrated floral infection in wheat smut. Nakagawa (1898) infected the flowers of wheat with the mature spores of loose smut. Hori (1907) while working with *Ustilago tritici* and *U. nuda* concluded "that the spores of those smuts which mature at the flowering time of the host, and may be scattered easily by the wind, will be retained in the inner side of the seed and give rise to smut disease during the next flowering time of the host-plant". Brefeld (1903) in the course of his investigations with the wheat smut and Hecke (1904) with barley successfully carried out infection through the flower. Hecke (1905) conclusively demonstrated the mycelium in the embryo and remarked that "the smut-germ then lives intraseminally until the grain sprouts in the spring, after which it grows along with the host". Thus, in all the cases mentioned above, the infection is perpetuated through the seed year after year, the infection taking place at the flowering time of the host.

Various techniques have been employed to cause artificial floral infection. Brefeld used an India-rubber ball to give a shower of spores on the flowers. Halle method consists in the artificial infection of each flower, just as in cross-pollination, using a fine camel's hair brush to dust the spores on the stigma of the flowers. Moore (1936) devised an apparatus for inoculating the flowers *in vacuo*. Oort (1939) suggested a few improvements over that of Moore. Mundkur and Pal (1941) introduced some more modifications in Oort's method. The following two techniques have been employed in the present investigations :

(*a*) Dusting the stigma of flowers with sporeballs and in stages where stigma is not protruding out, placing the spores at the tip of the flowers.

(*b*) Inoculation *in vacuo* with slight modifications to suit experimental conditions.

In order to determine the stage at which artificial infection is successful, it was found necessary to study the details of the structure of the inflorescence in relation to the individual units (flowers) composing it. The *bajra* inflorescence is composed of racemes of heteromorphous spikelets so arranged on a central axis as to form a compact column which in the early stages is entirely enclosed in a sheathing leaf. With growth, the sheath opens from top downwards forming more or less a 'Y'-shaped fold. The maturation of the flowers starts from the tip and proceeds towards the base of the inflorescence. It is possible that the lowermost flowers are formed first and the uppermost later, but the lowermost flowers mature later. Usually there are four flowers in a spikelet, 2 on either side of the axis. One of the two is a normal hermaphrodite flower, whereas the other adpressed to it a little below, is a reduced flower, male or rarely neuter.

In the youngest flower the glumes enclose a small carpel with a short style and ill-developed stigmatic lobes. With development, the style elongates, the glumes slightly open and the two lobes of the stigma peep out of the flower. A little later the stigmatic lobes open out completely. The style gradually elongates and finally reaches its final form. Meanwhile, the ovule in the ovary also begins to develop and the flower reaches the stage of fertilisation. After fertilisation, the tip part of the style dries and a constriction appears a little below the stigmatic joint from where the withered stigma detaches off leaving a sharp pointed style behind. This also falls off in due course. In the earlier stages a small style can be detected, attached to the developing fruit. The flowers are protogynous. About the stage when the stigma is just peeping out, the stamens start developing. The filament begins to elongate and when the stigma is mature, the anthers can be made out as small yellow spots at the mouth of the flowers. It is after the fertilisation of the flower and when the stigma shows withering that the anthers protrude out to assume a versatile nature. In rare cases the anthers can be seen projecting out with very small filaments before pollination.

In an inflorescence the uppermost flowers are found with shrivelled stigma and versatile anthers, a little lower, flowers with fully mature stigma and anthers peeping out. The middle flowers are with semi-developed peeping stigma and with totally enclosed anthers. The lowermost flowers, however, do not show any external signs of stigma or anthers, and the glumes are either loosely or closely adpressed. The presence of these stages varies with the stage of maturity of an ear. It should also be noticed that the stigma gradually peeps out with the opening of the sheath but during the wet season a few flowers with semi-developed stigma may be seen while still enclosed by the sheath.

For purposes of artificial inoculation, it was, thus, found possible to divide the entire ear into the following four stages of maturity according to the condition of the stigma :

(*a*) Ears enclosed within the sheathing leaf, wholly or partly, flowers young, stigma within the glumes, anthers in the course of formation.

(*b*) Flowers with peeping to semi-developed stigma, stigmatic lobes wide open. No external signs of anthers.

(*c*) Flowers with well-developed stigma, *i.e.*, ready for fertilisation. The anthers either non-visible or slightly peeping out of the flowers.

(*d*) Flowers with shrivelled stigma, anthers either hanging out or at least peeping.

It should be realised that there is no hard and fast line of demarcation between these stages. One stage passes gradually into the preceding and the next following one. An attempt was, however, made to confine the limits of each stage by girdling, *i.e.*, by removing flowers of the transitory stages and leaving definite stages of different categories (Plate XIV, Fig. 1). The ear to be inoculated may have all or any of the stages. For the sake of convenience one single stage was regarded as one unit inoculated.

The ears, from the earliest stage, *i.e.*, even when they were wholly enclosed within the sheathing leaf, were covered with sterilised butter-paper bags. The bags were removed only for purposes of inoculation. In some cases especially in stage I, it was often necessary to unfold the sheath but it was replaced soon after inoculation.

The experiments with inoculation *in vacuo* were entirely confined to potted plants, whereas the dusting method was extended to pots as well as the field. The results are summarised in Tables II and III for the two methods.

TABLE II

The effect of dusting the flowers with sporeballs

(*a*) *From* 10–9–1942 to 23–9–1942

Stage of maturity of the flowers during inoculation	Total No. of ears inoculated	No. of healthy ears	No. of diseased ears	No. of ears showing drying	Percentage of infection
Experimental—					
I. Flowers young and without stigma	85	14	58	13	68·2
II. Flowers with peeping to semi-developed stigma	55	16	29	10	52·7
III. Flowers with well-developed stigma	70	22	38	10	54·2
IV. Flowers with shrivelled stigma and versatile anthers	44	35	1	8	2·2
Control—					
I. Flowers young and without stigma	74	68	4	2	5·4
II. Flowers with peeping to semi-developed stigma	38	36	2	..	5·2
III. Flowers with well-developed stigma	48	44	4	..	8·3
IV. Flowers with shrivelled stigma and versatile anthers	35	35	..	..	..

(*b*) *From* 24–9–1942 *to* 10–10–1942

Stage of maturity of the flowers during inoculation	Total No. of ears inoculated	No. of healthy ears	No. of diseased ears	No. of ears showing drying	Percentage of infection
Experimental—					
I. Flowers young and without stigma	85	14	53	18	62·3
II. Flowers with peeping to semi-developed stigma	56	14	32	10	57·1
III. Flowers with well-developed stig ma	50	24	16	10	32·0
IV. Flowers with shrivelled stigma and versatile anthers	39	39	..	..	..
Control—					
I. Flowers young and without stigma	76	60	8	8	10·5
II. Flowers with peeping to semi-developed stigma	64	60	..	4	..
III. Flowers with well-developed stigma	30	27	..	3	..
IV. Flowers with shrivelled stigma and versatile anthers	40	38	..	2	..

(*c*) *From* 15–10–1942 *to* 31–10–1942

Stage of maturity of the flowers during inoculation	Total No. of ears inoculated	No. of healthy ears	No. of diseased ears	No. of ears showing drying	Percentage of infection
Experimental—					
I. Flowers young and without stigma	126	26	30	70	23·8
II. Flowers with peeping to semi-developed stigma	81	37	9	35	11·1
III. Flowers with well-developed stigma	60	46	4	10	6·6
IV. Flowers with shrivelled stigma and versatile anthers	47	45	..	2	..
Control—					
I. Flowers young and without stigma	81	31	1	49	1·2
II. Flowers with peeping to semi-developed stigma	79	37	..	42	..
III. Flowers with well-developed stigma	60	48	..	12	..
IV. Flowers with shrivelled stigma and versatile anthers	43	40	..	3	..

TABLE III

The effect of inoculation in vacuo *with sporeballs*

(*a*) *From* 10–9–1942 *to* 23–9–1942

Stage of maturity of the flowers during inoculation	Total No. of ears inoculated	No. of healthy ears	No. of diseased ears	No. of ears showing drying	Percentage of infection
Experimental—					
I. Flowers young and without stigma	107	19	52	36	48·5
II. Flowers with peeping to semi-developed stigma	85	23	40	22	47·0
III. Flowers with well-developed stigma	62	23	24	15	38·7
IV. Flowers with shrivelled stigma and versatile anthers	49	41	..	8	..
Control—					
I. Flowers young and without stigma	70	45	3	22	4·2
II. Flowers with peeping to semi-developed stigma	53	40	2	11	3·7
III. Flowers with well-developed stigma	52	41	2	9	3·8
IV. Flowers with shrivelled stigma and versatile anthers	44	39	..	5	..

(*b*) *From* 24–9–1942 *to* 10–10–1942

Stage of maturity of the flowers during inoculation	Total No. of ears inoculated	No. of healthy ears	No. of diseased ears	No. of ears showing drying	Percentage of infection
Experimental—					
I. Flowers young and without stigma	125	25	52	48	41·6
II. Flowers with peeping to semi-developed stigma	43	21	13	9	30·2
III. Flowers with well-developed stigma	70	42	18	10	25·7
IV. Flowers with shrivelled stigma and versatile anthers	38	36	..	2	..
Control—					
I. Flowers young and without stigma	56	38	4	14	7·1
II. Flowers with peeping to semi-developed stigma	44	29	3	12	6·8
III. Flowers with well-developed stigma	36	27	1	8	2·7
IV. Flowers with shrivelled stigma and versatile anthers	44	40	..	4	..

(*c*) *From* 15–10–1942 *to* 31–10–1942

Stage of maturity of the flowers during inoculation	Total No. of ears inoculated	No. of healthy ears	No. of diseased ears	No. of ears showing drying	Percentage of infection
Experimental—					
I. Flowers young and without stigma	70	18	18	34	25·7
II. Flowers with peeping to semi-developed stigma	36	11	7	18	19·4
III. Flowers with well-developed stigma	42	15	6	21	14·2
IV. Flowers with shrivelled stigma and versatile anthers	34	26	..	8	..
Control—					
I. Flowers young and without stigma	51	20	1	30	1·9
II. Flowers with peeping to semi-developed stigma	31	7	..	24	..
III. Flowers with well-developed stigma	32	14	1	17	3·1
IV. Flowers with shrivelled stigma and versatile anthers	29	20	..	9	..

A critical study of Tables II, and III shows that by both dusting and inoculation *in vacuo* the maximum amount of disease appears when the ears are inoculated at Stage I. The second stage gives more or less the same result but shows a definite decline, though not sudden. Stage III is much less susceptible whereas it is not possible to carry out successful inoculations at Stage IV.

On the basis of the results obtained from the infection experiments by dusting as well as by inoculation *in vacuo* it is possible to divide the entire period into three distinct stages (Tables II *a*, II *b*, II *c* and III *a*, III *b* and III *c*). This division is not only based on the number of ears affected but also on the relative percentage of smutted grains appearing per ear. The first period ranged from 10–9–1942 to 23–9–1942, when the rains were quite frequent with the result that a humid atmosphere was maintained. During this period maximum number of smutted grains made their appearance in the ears and comparatively few remained healthy (Pl. XIV, Fig. 2). During the second period when the rains were occasional a fall was noticed and each infected ear exhibited 30–50 sori (Pl. XIV, Fig. 3). The last period which had no rainfall showed the least disease, both as regards the number of affected ears as well as the number of affected grains per ear. There were only 3–15 such grains (Pl. XIV, Fig. 4).

As far as the suitability of the method for the floral infection of *bajra* is concerned, the results show that the dusting method is superior to the inoculation *in vacuo* In the former, larger number of diseased grains appear and at the same time requires no elaborate apparatus though dusting of individual flowers takes time. Further, in this method, the removal of the sheathing leaf from ears of Stage I, which is essential

for purposes of inoculation *in vacuo*, can be avoided with the result that larger number of ears of Stage I show drying in the second method.

Sporidial infection.—Floral infections were also brought about by inoculating individual flowers with drops of sporidial suspension obtained by germinating the spores in 0·5% malt extract at 35° C. with an artificial light exposure of 10 hours and later incubation in darkness (Bhatt, unpublished). Out of 452 flowers inoculated 202 of them developed into sori.

In the light of the observations as on the period of high susceptibility, a survey of the cultivated fields round about Lucknow was made. Two localities were selected—one near Kukrail about 5 miles from Lucknow and the other near the Paper Mill area about 2½ miles. The observations recorded are a total of random counts made in the first and the second week of September and the first week of November. The results are presented in Table IV.

TABLE IV

The variation in the extent of disease during two periods of susceptibility

Time of count	Locality	Total No. of ears examined	No. of diseased ears
2nd week of September 1942 (Early sown)	Kukrail	562	247
1st week of November 1942 .. (Late sown)	,,	463	43
1st week of September 1942 .. (Early sown)	Paper Mill area	Nearly whole field	Almost all
1st week of November 1942 .. (Late sown)	,,	523	59 (With few sori)

It will be seen from the above table that both in Kukrail as in the Paper Mill area there is more disease during the first and second week of September than in the first week of November. The number of smutted grains per ear is also found to vary with the periods mentioned, *viz.*, during the first period the infected ear showed quite a large number of sori whereas in the second period the number of sori varied from 1 to 4. The excessive disease found in the Paper Mill area is not so much due to any change in the humidity of the atmosphere as due to other factors in the soil.

EFFECT OF ATTACK ON THE HOST

A study of an infected ear reveals that a few spikelets consisting of the hermaphrodite flowers are affected, the male and the neuter ones escape as far as the smutting is concerned, though in a few cases mycelium has been located in the cavity of the male flowers. The diseased as well as the healthy plants look alike except in the region of the ear, there being neither stunting nor any change in any of the parts. Repeated attempts to find out a mycelium in any region of the

root, leaf, stem and the floral axis by maceration as well as sections were unsuccessful. The change is entirely confined to the pistillate flowers.

The glumes are usually unaffected, on rare occasions they may show a pale colour. Even though the attack may be early, the pistil can be distinguished as a separate organ externally. In the early stages the infected ovary is covered by the glumes and therefore, is not visible externally. Gradually it enlarges, the glumes open out and becomes visible outside. The infected ovary shows slight variation with regard to size and shape. In the earliest detectable stage the sorus membrane is greenish in comparison to the healthy grains which are more or less shining white. The colour becomes darker with age. In the course of maturation, the colour again changes. At first the tip becomes slightly brown which gradually extends to the whole of the grain, and finally becomes dark-brown. The tip is marked with a black spot where rupturing occurs.

Unlike *Sphacelotheca sorghi* (Kulkarni, 1918) the ovary infected by *Tolyposporium Penicillariæ* retains its individuality and is not fused with other members of the flower. But in a few cases, though very rarely, the bases of the anther filaments were seen to be blended with the pistils, the anthers proper and a part of the filaments remaining free. Thus a few sori were collected with versatile anthers still attached. The style never escapes infection and at times, in the early stages, is seen attached to the tip of the affected grain. Eventually it also dries up and vanishes.

The mature sorus is like a pear-shaped body projecting out of the glumes. It is bluntly rounded and conical at top. It is 3–4 mm. in length and 2 to 3 mm. in breadth. On ripening the membrane presents a few cracks at the top, which finally ruptures, exposing and scattering the spores to nature. The sorus is left behind almost empty with only a few sporeballs at the bottom. A critical observation on the position of the sori in an ear showed that a larger number of them are developed under the sheath especially during periods when the humidity of the atmosphere was not high.

Course Taken by the Infecting Hyphæ

To study the course taken by the infecting hyphæ in a flower infected by *T. Penicillariæ*, sori of various stages of maturity were collected from the *bajra* fields round about Lucknow. Also a certain number of samples were fixed from time to time from experiments dealing with the artificial infections of the flowers by the dusting method. The samples were fixed in Formalin-Acetic-Alcohol and Navaschin's fixing fluids. They were examined in microtome sections, 10–15 μ thick, stained with hæmatoxylin and counterstained with orange 'G'.

In the preparations the sporeballs have been seen to germinate on the stigma. Though the actual entry of the infecting hypha has not been detected, the first traces appear in the stigmatic region

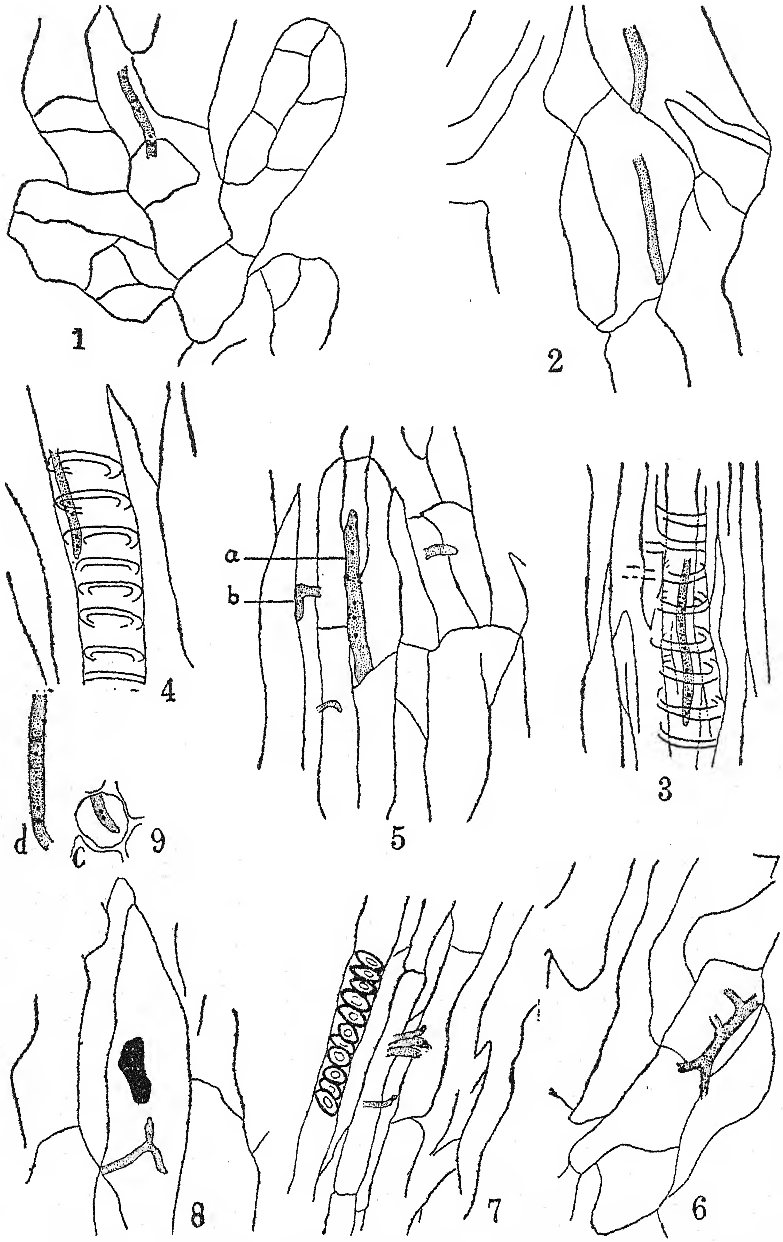
(Text-figs. 1 and 2). On crossing the stigmatic lobes, the mycelium enters the style. In this region it measures about $1 \cdot 5\,\mu$ in thickness and at places has been noticed to traverse through the xylem (Text-figs. 3 and 4). The infecting hyphæ become quite clear at the base of the style, *i.e.*, between the point of its attachment to the ovary and the point from where the stigma detaches off after fertilisation (Text-fig. 5). In this part the hypha is quite thick, measuring about $2 \cdot 5\,\mu$ in width, and exhibits a number of nuclei, disposed off quite close together but no septa could be made out (Text-fig. 5 *a*). The hypha does not show much lateral spread except at few places one or two thinner branches, measuring $1 \cdot 7\,\mu$ in width, are given out entering the neighbouring cells (Text-fig. 5 *b*). On reaching the base, the hyphæ enter the upper wall of the ovary where they extend on both sides. It occupies its position between the pericarp and the aleurone layers and sends out numerous branches to the neighbouring tissue (Text-fig. 13). The mycelium is intra- or inter-cellular, $1 \cdot 8$ to $2\,\mu$ thick, with 2–4 lobed haustoria. The mycelium, from here, gradually advances towards the base of the ovary through the sidewall, where again the branching is copious, the path is more or less direct, maintaining itself between the pericarp and the aleurone layers (Text-fig. 7). The haustorial formation in this region is limited and very rarely one or two can be seen (Text-fig. 8).

The infecting mycelium takes two courses. Most of the hyphæ proceed towards the thalamus, whereas others, after repeated branching, attack the ovary proper from the sides so that in a few sori the upper ovary cavity may be full of mycelium without the ovule being attacked. In the former method after the hyphæ have reached the thalamus region, they branch profusely and ramify copiously, the distribution is localised to particular tissues. The mycelium becomes inter- or intra-cellular with numerous haustorial branches. In this region it measures $1 \cdot 2$ to $1 \cdot 8\,\mu$ in width and at places shows two nuclei (Text-fig. 16). Further advance downwards is checked, whereas the upward advance is considerably facilitated. Text-fig. 18 shows the distribution of the mycelium in the region of the thalamus and the differentiation of the tissue responsible for the complete absence of mycelium in the region of stalk. There is abundant mycelium in the tissue just below the ovary. The central part is comparatively free. The lowermost region again shows quite an extensive mycelium.

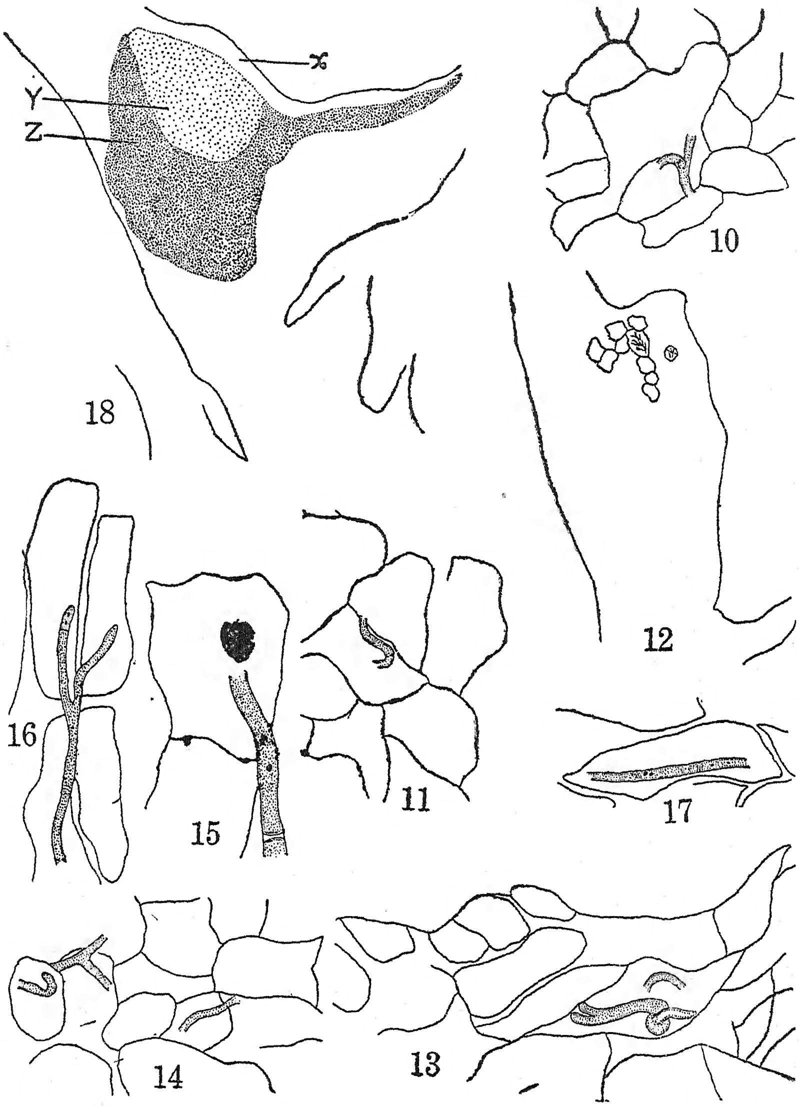
Simultaneously, the invading hyphæ begin to advance towards the funicular end of the ovule and it is through the nucellus and the micropyle that the actual invasion of the ovule and the starchy endosperm starts. The infecting hypha measures about $1 \cdot 7\,\mu$ in thickness.

The invasion of the tissues concerned is gradual and unlike *Ustilago nuda* (Butler, 1918) the tissue is absorbed during growth and its subsequent development. Various stages in the utilization of the tissue can be made out, so that at a fairly advanced stage the ovary cavity is seen divided into 2 or more chambers, the intervening tissue being formed by the host in the course of invasion and absorption.

Thus, the invasion of the ovule takes place through the funicular end and at times the starchy endosperm may also be invaded from the

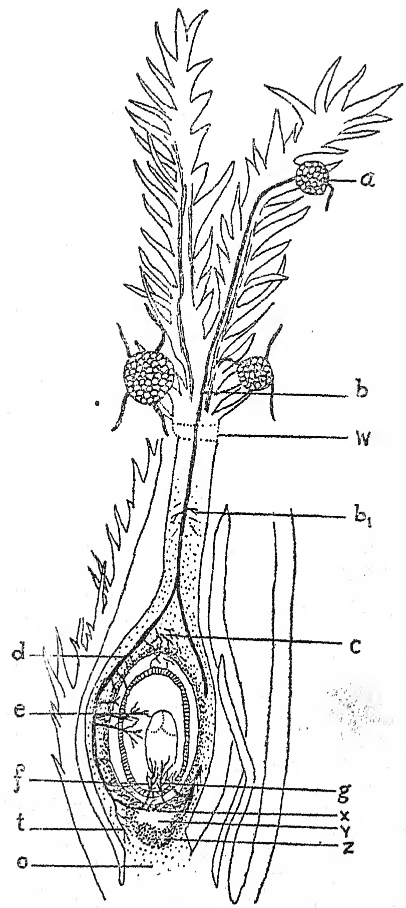


Text-Figs. 1-9. The course of the infecting hypha in a *bajra* flower in Fig. 1. Stigmatic lobe, × 820. Fig. 2. Region of stigma, × 820. Figs. 3 and 4. Xylem of style, × 820. Fig. 5. Region of lower style. *a.* main hypha with 5 nuclei (septa not clear) and *b.* thinner branches, × 940. Fig. 6. Tissue connecting the style to the ovary × 740. Fig. 7. Side wall of ovary between the pericarp and the aleurone layer (walls partially gelatinised), × 615. Fig. 8. Sidewalls of ovary with a two lobed haustorium, × 615. Fig. 9. Binucleate hyphæ in *c,* a cell of the sidewall, *d,* ovary cavity, × 940.



Text-Figs. 10–18. Showing the course of infecting hypha in a *bajra* flower in Figs. 10 and 11. Below the ovary cavity, × 940. Fig. 12. Cells of thalamus (gelatinised), × 60. Fig. 13. Upper wall of ovary, × 740. Fig 14. Thalamus region towards stalk-end, × 740. Fig. 15. Uninucleate hypha from upper wall of ovary, × 1220. Fig. 16. Hypha at lower end of ovary wall (tip cell binucleate) × 800. Fig. 17. Binucleate hypha from the tissue in the starchy endosperm during the process of invasion, × 800. Fig. 18. L. S. of the thalamus of the flower. *x*, and *z*, regions with abundant mycelium, *y*, comparatively free, × 80.

sidewalls of the ovary. The hyphæ are either uninucleate (Text-fig. 15) or binucleate (Text-figs. 9, 16 and 17). The course of the infecting hyphæ is shown in Text-fig. 19.



Text-Fig. 19. The course of hypha in an infected flower (stamens removed). Reconstructed from a series of sections.

a–Sporeball germinating on stigma ;
w–Region from where the stigma detaches off from the style ;
b–Main infecting hypha along the stigma and style ;
b_1–Branches from the main hypha, invading the stylar tissue ;
c–Hyphæ in the region of upper wall of ovary, showing copious branching ;
d–Main hypha along the sidewall of ovary (between pericarp and the aleurone layer in a developing fruit) ;
e–Branches from main hypha invading the starchy endosperm :
f–Hyphæ at the funicular end attacking the ovule ;
g–Hyphæ below ovule showing copious branching ;
x–Region just below the ovary cavity with abundant mycelium which later shows gelatinization of the walls of the hyphæ ;
y–Region comparatively free from hyphæ ;
z–Lower end of thalamus with hyphæ which never gelatinize ;
o–Stalk-end of the flower free from mycelium.

Long before the complete absorption of the ovule and the starchy endosperm, the walls of the hyphæ in the region of the thalamus and in the sidewalls of the ovary begin to show gelatinization, whereby they become swollen and consequently the lumen of the hyphæ is reduced. Gradually the mycelium in the ovule and the starchy endosperm also become gelatinized to form the sporeballs. It may, however, be mentioned that the sporeball formation may go on with the simultaneous invasion and absorption of the tissues.

The infecting hypha takes about two weeks to cover the entire passage from the point of infection to the time of mature sporeball formation ready for dissemination. But this incubation period may vary according to the stage at which the infection is brought about.

Perennation of the Fungus

In *Ustilago tritici* and *U. nuda*, the smuts of wheat and barley, where the infection is floral, a dormant mycelium perennates in the seed. This mycelium, on germination of the seeds, enters the seedlings, remains in the host throughout its growth, maintaining itself at the growing point, and causes infection when the plants are flowering. In order, therefore, to find out if *T. Penicillariæ* behaves similarly, two types of seeds were sown as usual in 2 cm. dibbles in pots.

(*a*) Apparently healthy seeds from the previous season's artificially infected ears, inoculation being carried out *in vacuo*.

(*b*) Healthy seeds from totally healthy ears.

The seeds were surface-sterilized by washing them in 0·1% mercuric chloride for five minutes and the ears were covered by butter-paper bags to guard them against infection through the flower. The results are given in Table V.

Table V

The extent of disease due to sowing of seeds from totally healthy and artificially inoculated ears

No. of seeds sown	Total No. of ears produced	No. of healthy ears	No. of diseased ears
	Healthy seeds from inoculated ears		
50	52	48	4
	Healthy seeds from healthy ears		
50	52	49	3

It will be seen from the observations recorded in the table that the seeds taken out from the inoculated ears as well as from the absolutely healthy ones behave similarly, the percentage of disease in both cases being more or less the same, as regards the number of smutted ears and also the number of smutted grains per ear. Further, an examination of seeds from artificially infected ears by sectioning

showed no trace of a dormant mycelium. It will, therefore, become evident that the seed plays no part in the initiation or the spread of the disease due to *T. Penicillariæ*.

Since it was established experimentally that the disease in *bajra* is due to floral infection, it was evident that the soil plays an important part in the initiation of the disease every year inasmuch as the spores of *T. Penicillariæ* must remain dormant in the soil and germinate out in the favourable season to produce the disease. This was corroborated by the observations made on the recurrence of the disease for three successive years in an experimental plot of the Department and also from observations made in the fields in the neighbourhood of Lucknow. It was found that the intensity of the disease goes on increasing year after year, where *bajra* is cultivated during successive seasons. Thus in an experimental plot where no crop had been grown during the last 5 to 7 years it was noticed that in the first growing season (1940) there were only 9 infected ears out of a total of 762 produced. In 1941, forty-eight diseased ears appeared in a lot of 344 and finally in 1942, there were as many as 104 heavily infected ears in a total of 442.

The observations mentioned above clearly indicate the importance of soil, serving as a depository of infection. It was, therefore, found necessary to study the viability and the germinating capacity of the spores when kept under different conditions in the soil of the experimental plot. Small glass tubes about 4″ in length were filled as follows and buried in the soil at a depth of 6″ in a horizontal position at the end of the *bajra* season.

(*a*) Sporeballs only, the glass tube being sealed at both ends by melting.

(*b*) The tube filled with sporeballs, the two open ends being plugged with cotton.

(*c*) Tube filled with soil infested with sporeballs of *T. Penicillariæ*, the ends being plugged with cotton.

(*d*) Tube filled with entire, undamaged, surface-sterilised sori and cotton plugged and

(*e*) Tube filled with dry sporeballs, and preserved under laboratory conditions to serve as control.

It will be seen that the spores in tube (*a*) were cut off from the external atmosphere where as those of (*b*), (*c*) and (*d*) were constantly in communication with the atmosphere of the soil. A record was maintained of the soil temperature. The highest temperature reached in summer, during the experiment, was 49° C. Samples were taken out at regular intervals of 15 days and examined till the beginning of the next *bajra* season (July 1943) for the state in which the spores exist and the variation in the viability due to burying.

The results showed that the spores in all the tubes passed the whole of the winter and the following summer without any appreciable change in their state though there was an indication of a slight fall in the

percentage of germination. In the month of June, after 8 months in the soil, when examined two days after the first shower of rains, the spores did not exhibit any change of state nor was there any change in the germination capacity. In July when there were constant rains an examination revealed that in tube (*a*) the spores were unaltered whereas in tube (*b*) and (*c*) clear white specks of mycelia could be seen with the naked eye. On low speed centrifuging sporeballs in a perfect stage of germination were separated out from the spore-mixed soil of tube (*c*). In tube (*d*), few mycelial specks were noticed on the surface of the sori that had ruptured due to wetting. With the advance in the season larger number of spores from tube (*c*) were recorded in a perfect state of germination. The ungerminated spores from the tubes (*b*) and (*c*) when tested for germination under optimum conditions in hanging drop cultures showed only a limited amount of germination, indicating that either they had already germinated in nature or that they had lost their viability completely.

Discussion

The results of the infection experiments carried out have conclusively established that the infection of the *bajra* plant by *Tolyposporium Penicillariæ* takes place only through the flower. The possibility of the various other modes of infection (seedling, shoot and localised) have also been worked out by the spores and mycelium from them on germination and even though the spores and the host have been provided with the optimum conditions, the mycelium failed to penetrate inside the plant. That the mycelium is unable to attack the root of the plant is also shown by the observations made on a *bajra* ear showing viviparous germination (Bhatt, 1943) where the roots were in direct contact with the neighbouring sori. A few experimental plants showed a number of diseased ears, but the percentage was not significantly different from the one found in the control.

Like *Ustilago tritici* and *U. nuda*, the infection takes place through the flower, but whereas in *U. nuda* the infection is brought about at the midanthesis stage when the ephemeral cells of the style have begun to collapse and dry up (Butler, 1918), in *Tolyposporium Penicillariæ*, it is brought about before pollination. A study of the infection tables reveals that Stage I, where the flowers are young and enclosed within the glumes without any external signs of stigma or anthers, gives a high percentage of disease irrespective of the time of the season during which the infection experiment is carried out. The extent of disease in Stage II (where the flowers show peeping to semi-developed stigma) is almost the same as in Stage I and is due to the fact that the difference between the first two stages is so small that by the time the sporeballs germinate and are ready to cause infection, the flowers enter the second stage. Stage II exhibits appreciable difference in the percentage of infection during drier periods. The difference is not due to the stages being different, but as can be easily realized due to the variation in the moisture content of the atmosphere; thereby the spore germination is delayed. But when the spores have reached the infective stage, the flowers had developed into the next stage of maturity and are

consequently less susceptible. The percentage of disease in Stage III (flowers with well-developed stigma) is considerably lower than the one found in Stage I and II, indicating that the flowers at this stage are less susceptible. It might, however, be mentioned that the stage is so critical that the delay of a few hours may pollinate the flowers first, with subsequent withering of the stigmatic lobes and hence the chances for infection are reduced to the minimum. In Stage IV (where the flowers were with shrivelled stigma), no diseased ears were obtained as the stigma had already withered off and no infection was possible. Thus an analysis of the stages of infection and the relative percentage of disease in them justifies the arbitrary divisions made with regard to the susceptibility of the *bajra* flowers.

The importance of the influence of environmental factors on the percentage of disease by the various smuts has been shown by Johnston (1927), Reed and Faris (1924), Smith (1932), Ling and Moore (1937), and Rodenhiser and Taylor (1940). In *Tolyposporium Penicillariæ*, the disease and the number of smutted grains per ear is controlled by the temperature and the humidity conditions of the immediate environment. In the infection experiments carried out, the susceptibility of the flowers of the first three stages is directly related to the atmospheric conditions prevailing at the time of infection experiments which has been divided into three definite periods. The first period has humidity and temperature conditions most favourable for spore germination resulting in a very high percentage of infection. In the second period which is comparatively drier, (the temperature more or less remaining the same), the infection is comparatively poor. In the last period, when the humidity is much less and the temperature conditions also unfavourable, the disease is at its minimum.

The first appearance of disease in *bajra* due to *T. Penicillariæ* is of considerable importance since no dormant mycelium is found to perennate inside the seed as is found in *Ustilago nuda* (Hecke, 1905) and other smuts where infection through the flower takes place. The experiments conducted to ascertain the amount of disease by sowing the sterilised and unsterilised and spore coated seeds have confirmed beyond doubt that the infection is not seed borne. On the other hand the observations extending to the field as well as the laboratory show that the soil serves as a depository for the smut spores. The spores pass the whole of the winter and the following summer in the soil without in any way losing their viability and germinate during the rains to initiate the infection if the host is available. The possibility of an alternate host for the fungus, as suggested by Ajrekar and Likhite (1933), can be excluded in the light of the results mentioned above.

The effect of infection on the host is confined to the flower alone and does not extend beyond it to the other parts. The hypha penetrates the flower through the stigma from where it reaches the upper wall of the ovary, traversing the whole length of the style, without much lateral spread. It takes its position between the aleurone layer and the pericarp. The mycelium is binucleate, inter- and intra-cellular, exhibiting slight branching with two to four-lobed haustoria. The downward advance is continued through the wall of the ovary to the

thalamus. In this region it branches profusely and ramifies copiously, advancing towards the funicular end, and finally invades the ovule. The absorption of the developing embryo and the surrounding starchy endosperm is gradual. At times the starchy endosperm is invaded first by the mycelium from the side walls of the ovary. In such cases the ovule is attacked much later. Before the whole of the tissue is involved, the walls of the hyphæ begin to gelatinize to form the spore-balls. The entire process from the time of infection to the formation of sporeballs ready for dissemination takes about two weeks, but this period may vary slightly according to the stage at which infection takes place. Thus *T. Penicillariæ* differs from *U. tritici* and *U. nuda* where the infecting hypha enters the host after pollination and does no harm to it. The incubation period in the latter is also much longer.

From the above studies it seems clear that if the late varieties of *bajra* are cultivated, the damage due to disease will be reduced to minimum as the flowers will escape the period of highest susceptibility for they will reach the first three stages at a time when the conditions for spore germination are very unfavourable.

Summary

The paper deals in detail with the various modes of infection of the *bajra* plant by the smut *Tolyposporium Penicillariæ*.

Attempts to cause seedling, shoot and localised infections (using various methods) by the spores and the mycelium obtained from them on germination have yielded negative results. The mycelium, even, fails to enter the tissue of the host.

The infection takes place through the flower. Four stages, based on the development of the stigma, have been tried to bring about floral infection. Young flowers showing no external signs of the stigma or anthers are the most susceptible. The later stages show comparatively less infection and finally no infection is possible when the flowers have been pollinated. Two methods—dusting the stigma with spore-dust and inoculation *in vacuo* have been employed. On the basis of the results obtained, the suitability of methods has been discussed.

The percentage and the degree of infection in a given variety have been found to stand in direct relation to the humidity of the immediate environment. The variations due to atmospheric conditions have been studied.

The investigation includes observations on the effect of attack on the host and the course taken by the infecting hypha. The incubation period has been found to last for two weeks, but may vary according to the stage of maturity at which infection has been brought about. The seeds are entirely free from dormant mycelium. The results indicate that seeds are in no way responsible for initiating the disease, but the soil has been found to serve as a depository for the smut spores, where they pass the whole of the winter and the following

summer without much change in their viability. They germinate during the rains and cause infection if the proper host is available.

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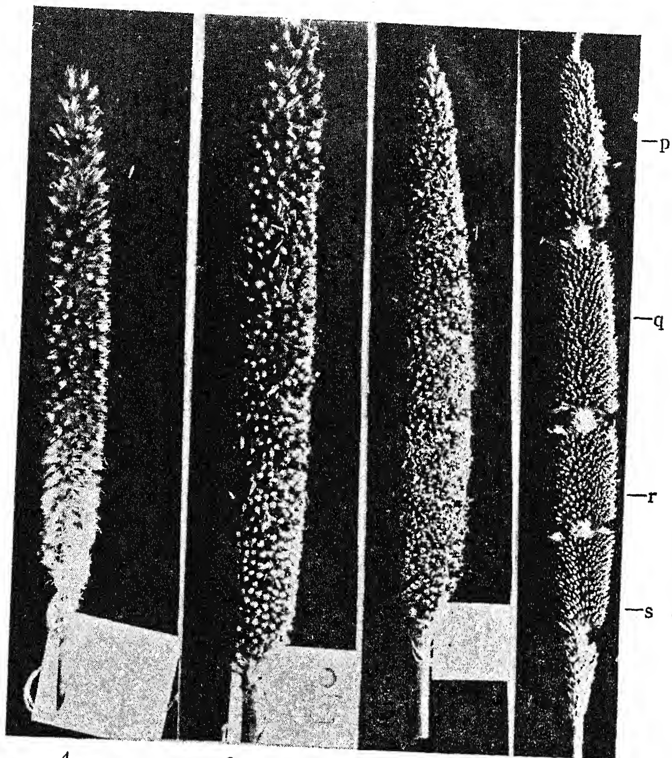
EXPLANATION OF PLATE

Fig. 1. Photograph of *bajra* ear showing 'girdling' to define the limits of the different stages of flowers. × ½.

- *p.* flowers with shrivelled stigma and versatile anthers.
- *q.* flowers with well-developed stigma.
- *r.* flowers with peeping to semi-developed stigma.
- *s.* flowers young, without external signs of stigma or anthers.

Figs. 2, 3 and 4. Photographs of infected *bajra* ears showing the intensity of disease during the three periods of the season. × ½.

- Fig. 2. Maximum number of sori in the first period.
- Fig. 3. Comparatively fewer smutted grains in the second period.
- Fig. 4. Very few infected grains in the last period.



R. S. BHATT—*STUDIES IN THE USTILAGINALES*

STUDIES IN THE DISEASES OF *MANGIFERA INDICA* LINN.

VII. Latent Infection in the Mango Fruit

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Introduction

Fruits of all stages beginning from the unfertilised ovary right upto the stage of maturity, as long as they are on trees, remain exposed to the atmosphere and come in direct contact with the fungal spores. Some of these spores lodge on the surface of the fruits, in the stomata or in the lenticels and continue in a viable condition without further development or in some cases germinate and produce infection hyphæ. The infection hyphæ penetrate the epidermis, pass into the tissues and remain dormant. These infections, although present in the fruits, are not detectable until such time as they produce the rot. It has, therefore, been termed as latent infection (Baker and Wardlaw, 1937).

It is, thus, expected that there must be a direct correlation between the fungi present in the orchard atmosphere, on the surface of the fruit and those present as latent infections.

In mangoes the problem of latent infections and its relation to the fungal flora of the orchards has been worked out by Baker and Wardlaw (1937) and Baker (1938). Sinha (Unpublished) working in this laboratory has shown that some of the storage rot in mangoes in Lucknow can be traced back to infection in the orchard and incidentally also the fungal flora in Lucknow mango orchards is considerably different from that in Trinidad. The work of Sinha as regards the orchard fungi has been extended by the present authors and the problem of latent infection has been worked out in detail for one fungus and the mechanism of latent infection and the mode of perennation of the fungus inside the fruit have been elucidated. The results are embodied in this paper.

Material and Method

Two varieties of mango fruits—khajli and phajli—were mainly employed for the investigations. The distribution of the fungal organisms and its relation to the latent infection were studied for the Begumbagh orchard, in Lucknow.

The methods for the collection of the superficial fungi and the study of the fungal flora were the same as suggested by Baker and Wardlaw (1937). The standard synthetic medium was generally used, glucose agar being employed only for plating the surface washings of the mango fruits.

The artificial production of latent infection was attempted by two methods only, *i.e.*, the general spray of a concentrated conidial suspension and an application of conidia on superficial wounds. Samples of the experimental mangoes were periodically examined either in cuticular preparations by macerating the tissues in a mixture of potassium chlorate and nitric acid or in microtome sections, 16 μ thick, unstained or stained with Fleming's triple stain.

ORCHARD FUNGI

The distribution and concentration of fungi in the orchard were found out by exposing plates with the standard synthetic medium, in triplicates for a period of two minutes, at a height of 6 feet, at the four selected spots in the Begumbagh orchard at definite intervals covering the entire mango season. The exposed plates were brought to the laboratory in sterile containers and incubated at the room temperature. When after 3 or 4 days colonies had appeared they were carefully counted and each one was separately subcultured. Most of the cultures sporulated and could be identified, only a few remained infertile.

All together 13 different fungi—*Aspergillus nidulans, Aspergillus niger*, *Aspergillus* sp., *Acrothecium penniseti*, *Acrothecium* sp., *Alternaria* sp. 1 and sp. 2, *Spondylochladium* sp., *Fusarium* sp. 1, sp. 2, and sp. 3, *Penicillium* sp. and *Rhizopus arrhizus* are found to occur in the atmosphere of the orchard.

Some of these, *e.g.*, *Aspergillus nidulans, Aspergillus niger* and *Fusarium* sp. 1 and 2 occurred regularly throughout the season, though their relative concentrations varied with time. Other fungi only made an occasional appearance—*Penicillium* sp. only on two occasions, *Aspergillus* sp. and *Spondylochladium* sp. three times and *Rhizopus arrhizus* four times.

There is a good deal of variation in the number of colonies appearing at different times of the mango season and it is difficult to correlate the results as the factors affecting the concentration of the fungal spores in the orchard are many and variable.

Concentration of *A. nidulans* is greatest in the first three exposures, *i.e.*, from April to the third week of June, the period during which the fruits are small or are gradually passing into the medium stage. *A. niger* and *Fusarium* sp. 1 begin with a high concentration which gradually falls and again rises. *Alternaria* sp. 1 and *Acrothecium penniseti* are fairly common and *Alternaria* sp. 2 and *Acrothecium* sp. 2 follow next.

SURFACE FUNGI

The fungi present on the outer surface of the mango fruits of different stages of maturity were obtained by washing the surface of the fruits under aseptic conditions using the method described by Sinha (Unpublished). The results are presented in Table I.

TABLE I

The concentration of fungi on the surface of mango fruits (total of 50 mangoes)

Strains isolated	Frequency of occurrence of the colonies					Total of 50 mangoes
	28-4-42	7-5-42	13-6-42	20-6-42	27-6-42	
Aspergillus nidulans ..	57	37	119	41	29	283
Aspergillus niger ..	..	8	18	64	21	111
Aspergillus sp. ..	..	..	13	7	6	26
Acrothecium sp. ..	..	..	..	51	60	111
Alternaria sp. ..	9	..	59	32	28	128
Fusarium sp. 1 ..	12	6	12	..	6	36
Fusarium sp. 2 ..	..	15	6	..	4	25
Rhizopus arrhizus ..	..	..	3	..	3	6
Penicillium sp. ..	..	..	1	..	1	2

The surface washing yielded 9 fungi. Among these strains *A. nidulans* was present constantly, the concentration being fairly large during the early periods which shows a slight decline when the fruits approach maturity. *A. niger* is absent during the earliest sample. *Alternaria* sp. and *Fusarium* sp. 1 are fairly common whereas *Acrothecium* sp. appeared towards the later part of the season. *Rhizopus arrhizus* and *Penicillium* sp. are much less frequently found. Sinha (Unpublished) could obtain only five fungi as the surface isolates. In the present investigations *Neocosmospora vasinfecta* was absent.

The concentration of the surface fungi shows no definite relation to time. But it will be noted that when the net charge of the fungal spores on the total number of 50 fruits is taken into consideration, the four fungi—*Aspergillus nidulans, Aspergillus niger* and *Acrothecium* sp., *Alternaria* sp. stand out prominently. *Fusarium* sp. 1 although shows a low concentration, is a pathogen which is present in quite a high concentration in the early season.

ISOLATION OF LATENT FUNGI

Latent fungi were isolated from surface sterilized mangoes of all stages beginning from the unfertilised ovary to the fully mature fruit just before the time of picking. The materials were surface-sterilised by washing them in a concentrated solution of borax for 20 minutes, steeping them in 0·1% mercuric chloride for three to five minutes according to the stage of maturity and finally washing them several times in sterile distilled water. Surface washings of the fruits treated in this manner were found to be free from viable fungal spores. In the case of smaller fruits, the whole of the fruit was cut into pieces, and all the pieces were put on the standard synthetic medium. In the larger fruits, five cubes were rapidly taken out by means of a sterilised scalpel—2 from the upper tip, 2 from the equatorial region and one from the base. The fungi appearing after four days were recorded

and isolated in tubes. Pure cultures of the strains were obtained by subculture of monohyphal tips. The results are presented in Table II.

TABLE II

The fungi isolated from apparently healthy fruits of varieties Khajli and Phajli

Stage of maturity of fruits (length in mm.)	No. of fruits used for isolation	Number of fruits giving the strains				
		Aspergillus nidulans	*Aspergillus niger*	*Acrothecium* sp.	*Alternaria* sp. 1	*Fusarium* sp. 1
Var. Khajli						
Fertilised and unfertilised ovaries ..	30	..	..	..	..	22
3–5 ..	16	..	..	..	1	11
10–20 ..	20	1	..	..	1	..
30–55 ..	23	5	3	3	1	..
60–75 ..	15	5	1	..	..	..
75–95 ..	23	7	1	1	1	..
100–120 ..	17	6	2	..	..	1
Above 120 ..	14	4	2	..	1	3
Total ..	158	28	9	4	5	37
Var. Phajli						
Fertilised and unfertilised ovaries ..	20	..	..	..	..	15
3–10 ..	10	..	..	..	..	7
15–30 ..	20	..	2	..	1	7
30–50 ..	16	3	1	1	..	1
60–75 ..	15	4	2	1	..	..
75–95 ..	18	5	2	2	1	..
100–120 ..	13	4	2	1	1	..
Total ..	112	16	9	5	3	30

From the data presented in Table III it will be seen that out of 158 Khajli fruits, five fungi, *viz.*, *Aspergillus nidulans*, *Aspergillus niger*, *Fusarium* sp. 1, *Acrothecium* sp. 2, and *Alternaria* sp. 1 were obtained, the first three being more important. In the number tested 28 fruits gave *Aspergillus nidulans*, 9 *A. niger*, 4 *Acrothecium* sp. 2, and 5 *Alternaria* sp. 1 and as many as 37 *Fusarium* sp. 1. It will also be noted that most of the *Fusarium* sp. was obtained from the young unfertilised ovaries or from fruits 3–5 mm. in length. Its absence in the later stages is probably due to its being pathogenic with the result that the unfertilised ovaries and the young fruits infected with the fungus do not develop further. The first appearance of *A. nidulans* is made when the fruits are 10–20 mm. in length but only from one

fruit. Five fruits out of a number of 23 from the next stage (30–35 mm.) yielded *A. nidulans.*

The same fungi were isolated from the 112 Phajli fruits, viz., *A. nidulans* from 16, *A. niger* from 9, *Acrothecium* sp. 2 from 5, *Alterneria* sp. 1 from 3 and *Fusarium* sp. 1 from 30 mangoes. As before *Fusarium* mainly appeared in the earliest stage.

A comparison of the orchard fungi with Tables 1 and 2 shows that the 5 latent fungi are common with 9 occurring on the general surface and the 13 recovered from the orchard atmosphere.

Artificial Production of Latent Infection

Experiments were carried out to cause latent infection artificially and also to determine the period at which it takes place in nature. Only one strain, *A. nidulans*—the most commonly occurring fungus—was selected. This fungus in the later part of the season showed saltations in some culture plates but the infection and other investigations were continued with the original non-saltating strain. Two methods were employed.

(*a*) *Spray inoculation.*—The fruits of the two varieties while on trees were surface sterilised with rectified spirit and a spray of a concentrated conidial suspension of *A. nidulans* in 0·5% malt extract given for three successive days (for a few minutes every day) and left on trees without any attempt being made to guard the fruits against natural infection.

Most of the fruits remained healthy; some, however, showed dry-rot in which the fruit shrivels up considerably, the skin together with the inner tissue is thrown into numerous folds, and becomes very hard. Subsequent investigations have indicated that the disease is not due to *A. nidulans* but a physiological one. The problem is under investigation.

The apparently healthy fruits (the fruits that did not show any external sign of the disease even 14 days after the spray) were investigated for possible latent infection. A fixed number of fruits were brought to the laboratory and after thorough surface sterilization representative areas were placed in plates with the standard synthetic medium to recover the fungus present in the fruits.

As it was not possible to take the weight of the fruits at the time of artificial infection, an arbitrary division of the different stages of maturity was based on the length, *i.e.*, fruits below 75 mm. were termed as small (S), between 75 and 100 as medium (M) and above 100 as big (B). The results of the spray infection experiment on the two varieties are shown in Tables III and IV.

Tables III and IV show that small Khajli mangoes when sprayed with a concentrated conidial suspension, give 71·4% of latent infection. In the medium size, there is a considerable fall to 20·0% and in the big to 7·6%. The Phajli fruits gave more or less similar results, the percentage of infection being the greatest when the fruits are small, the later stages being less affected.

TABLE III

The effect of spray of concentrated conidial suspension of A. nidulans *on Khajli fruits of different stages of maturity*

Stages of maturity (Length in mm.)	No. of fruits sprayed	No. of diseased fruits after 14 days	No. of apparently healthy fruits	No. of fruits left on trees for future observation	No. of apparently healthy fruits planted	No. of fruits giving *A. nidulans*	Final percentage of latent infection
Experimental							
S (below 75) ..	42	18	24	17	7	5	71·4
M (between 75–100)	48	1	47	28	19	4	21·0
B (above 100) ..	56	..	56	30	26	2	7·6
Control							
S (below 75) ..	20	3	17	9	8	1	12·5
M (between 75–100)	23	..	23	11	12	1	8·3
B (above 100) ..	31	..	31	14	17	1	5·8

TABLE IV

The effect of spray of concentrated conidial suspension of A. nidulans *on the Phajli fruits of the different stages of maturity*

Stage of maturity (Length in mm.)	No. of fruits sprayed	No. of diseased fruits after 14 days	No. of apparently healthy fruits	No. of fruits left on trees for future observation	No. of apparently healthy fruits plated	No. of fruits giving *A. nidulans*	Final percentage of latent infection
Experimental							
S (below 75) ..	51	18	33	24	9	6	66·6
M (between 75–100)	32	2	30	15	15	3	20·0
B (above 100) ..	27	..	27	15	12	1	8·3
Control							
S (Below 75) ..	25	5	20	13	7	1	14·1
M (between 75–100)	20	1	19	10	9	2	22·2
S (above 100) ..	18	..	18	6	12	1	8·3

Latent infection was also found in similar unsprayed sets, being 22·2% in the medium Phajli fruits and 12·5% in the small-sized Khajli.

The results show that at an early stage of development when the fruits are small the fungus can lodge itself securely in the fruit as latent infection. But apparently in the medium and big fruits the fungal spores are unable to get a hold. Spraying at the later (medium and

big) stages, therefore, does not make any appreciable difference regarding latent infection.

The 109 Khajli and 83 Phajli fruits, left on trees for further observations on latent infection after the spraying treatment, showed that all of them remained healthy till they were on trees. Towards the end of the season, these mangoes were removed to the laboratory where they were surface sterilised by borax and mercuric chloride and wrapped in sterile papers, the stalk-end being sealed with wax to minimise loss due to evaporation in storage. The fruits were incubated in glass cases at the room temperature. The mangoes were examined after 9 days for rotting. The results are given in Table V.

TABLE V

The number of uninfected and artificially infected fruits rotting in storage (Khajli and Phajli)

Stage of maturity at which infected (Length in mm.)	Experimental		Control	
	No. of fruits stored for ripening	No. of fruits showing rotting after 9 days	No. of fruits stored for ripening	No. of fruits showing rotting after 9 days
Var. Khajli				
(S) Below 75 ..	11	8	6	1
(M) Between 75–100	14	3	7	2
(B) Above 100 ..	21	4	9	2
Total ..	46	15	22	5
Var. Phajli				
(A) Below 75 ..	9	7	6	1
(M) Between 75–100	10	2	6	1
(B) Above 100 ..	7	1	4	..
Total ..	26	10	16	2

An examination of fruits, 5 days after storage, showed 6 to 8 greyish-black lesions distributed on the general surface of the fruits. Nine days later most of them had coalesced to form one big or 2 to 3 smaller rotting patches.

It will be seen from Table V, that out of 46 Khajli fruits, inoculated by the spray method at different stages of maturity, 15 of them rotted 9 days after storage and that mangoes below 75 mm. proved more susceptible. A comparison of Table V with Tables III and IV shows that the percentage of artificial infection obtained by plating the sprayed fruits is near about 70% in stage 'S' and 20% in stage 'M'. Nearly the same rotting percentage is given by the artificially infected fruits stored for ripening. The results, thus, indicated clearly that the

fungus, *A. nidulans* remained latent as long as the fruits were on trees and caused rotting during storage by becoming active pathogen.

TABLE VI

The effect of wound inoculation of Khajli fruits by Aspergillus nidulans

Stage of maturity (Length in mm.)	Total No. of fruits inoculated	No. of diseased fruits after		No. of apparently healthy fruits left on trees	No. of fruits plated after 14 days	No. of fruits giving *A. nidulans*	No. of fruits stored for ripening	No. of fruits rotted	Final percentage of latent infection
		14 days	2 months before transfer to storage						
Experimental									
S (below 75) ..	21	1	..	20	7	7	6	6	100·0
M (between 75–100)	39	1	3	38	15	13	9	9	91·6
B (above 100) ..	42	..	2	42	17	17	7	6	95·8
Control									
S (below 75) ..	10	..	..	10	4	..	4	..	..
M (between 75–100)	23	..	..	23	13	2	9	3	22·7
B (above 100) ..	24	..	..	24	13	2	8	1	14·2

TABLE VII

The effect of wound inoculation of Phajli fruits by Aspergillus nidulans

Stage of maturity (Length in mm.)	Total No. of fruits inoculated	No. of diseased fruits after		No. of apparently healthy fruits left on trees	No. of fruits planted after 14 days	No. of fruits giving *A. nidulans*	No. of fruits stored for ripening	No. of fruits rotted	Final percentage of latent infection
		14 days	2 months before transfer to storage						
Experimental									
S (below 75) ..	15	3	..	12	4	4	8	8	100·0
M (between 75–100)	29	4	..	25	12	12	9	8	95·2
B (above 100) ..	20	..	1	20	12	10	8	7	85·0
Control									
S (below 75) ..	12	2	..	10	4	..	4	..	..
M (between 75–100)	17	1	..	16	9	2	3	1	25·0
B (above 100) ..	15	..	..	15	9	..	2	..	..

(*b*) *Wound inoculation.*—The method consisted in making superficial punctures, involving minimum depth, in small areas on the mango fruits of different age while on trees and putting the inoculum of *A. nidulans* on the wound. This method ensures the entry of the fungus in the fruit. Fourteen days after infection representative parts from the inoculated areas of some of the fruits were examined in culture and the rest were brought to storage after two months. All the mangoes showed *A. nidulans* from the infected parts excepting two Khajli of the medium size and two Phajli of the big size. The results are given in Tables VI and VII.

State of the Fungus during the Period of Latency

By spores.—To study the mode of perennation, the sprayed fruits were periodically examined in cuticular preparations and both in hand and. microtome sections. It was found that in most cases the conidia were abundantly present and remained quite firmly lodged, on the general surface of the fruits as was also found by Kidd and Beaumont (1925) for apples. In two preparations only, conidia of *A. nidulans* and the hyphæ produced from them were also found in the substomatal cavity (Text-figs. 5 and 6). In the substomatal cavities, however, the conidia and the hyphæ remain well protected from the weather fluctuations until conditions become favourable for their germination and lateral spread. It may be mentioned that older fruits showed conidia only round about and on the lenticels but none in their cavities. Sinha (1945) has pointed out that in the mature condition the lenticels become covered over by the extension of the cuticle of the fruit.

By hyphæ.—The hyphæ of limited growth, presumed to be of *A. nidulans*, that remain dormant in the subcuticular region, are of more common occurrence (Text-figs. 4 and 5 *b*). Similar hyphæ whose identity has been definitely established by culture as *A. nidulans* have also been detected in the ducts and the cells of the outer-mesocarp (Text-figs. 7 and 8) of the fruits which were artificially infected at the stage 'S' (about 70 mm. in length) and gathered for investigations about the time of picking. It is, therefore, very likely that the hyphæ detected at the two places and at two different stages of maturity of the fruits are the same and that the subcuticular hyphæ resume their growth a little before the fruits are removed for storage.

That the fungus remains confined to the superficial layers is also proved by the fact that fresh surface sterilised cubes from mangoes, previously sprayed with the conidia of *A. nidulans*, when cut into hand sections and plated serially, invariably gave the fungus from the first two sections.

Penetration of the infecting hypha.—As most of the conidia are found to be present on the surface of the fruits (only a few in the substomatal cavity) and the hyphæ in the sub-cuticular region are considered to be the form in which the fungus survives the period of latency, it was thought desirable to study the mode of entry of the fungus into the mango tissue. There were two obvious methods for penetration : (i) the entry of the conidia lying near the stomata and the

lenticels into the cavities by means of germ tubes and (ii) the penetration of the cuticle by the infection hypha. For this purpose surface sterilised small fruits were placed in sterile moist chambers and inoculated with the conidia of *A. nidulans* at a number of places on the areas marked. The tissues from the marked areas were removed at regular intervals and fixed instantaneously for microtome sections and cuticular preparations by macerating the tissues in a mixture of potassium chlorate and nitric acid. It was noticed that the germ-tube from the conidia, on germination, spreads laterally on the skin (Text-fig. 1) until it makes its entry by a puncture in the cuticle (Text-fig. 2). The infecting hypha traverses the thickness of the cuticle where it meets the epidermis when it takes a turn (Text-fig. 3) and lodges itself between the cuticle and the epidermis (Text-fig. 4). Further growth of this hypha is arrested at this stage and it appears that due to certain factors, operating within the tissues, the hypha is unable to overcome the resistance offered by the innermost layers of the cuticle. A closer examination revealed that the cuticular layer is stratified as if one layer is deposited over the other. The one in immediate contact with the epidermal cells is denser and at times yellower which gradually thins out towards the periphery. Probably this difference determines the position taken by the hyphæ which may either lie against the outer epidermis or slightly above it. The subcuticular hypha remains in a dormant condition without proceeding further until the lowering of the tissue resistance due to various physical and chemical changes associated with growth and senescence of the fruits.

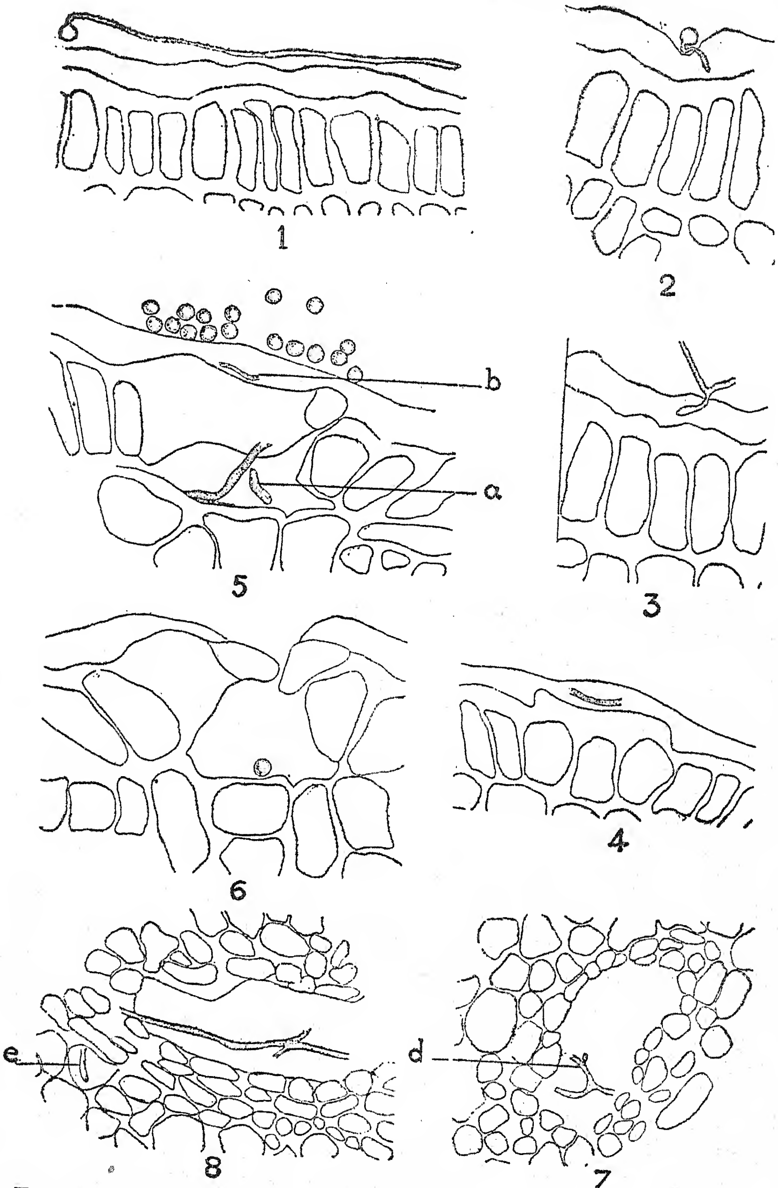
There is no structure comparable to the appressorium found in the present fungus as is reported for *Colletotrichum* by Dey (1919) and Simmonds (1941). Many hyphæ may infect the same fruit at a number of places. No external lesions or anthracnose spots could be noticed in the sprayed fruits but in the laboratory experiment small orange coloured areas developed where the hyphæ entered the cuticle.

Reaction of the Tissues to the Pathogen

The evidence available on the latent infection indicates that the development of the fungus is arrested at a very early stage and the infections are confined to the surface layers of the skin. Experiments were conducted to elucidate the reactions of the different tissues of the mangoes (epicarp and mesocarp).

With this end in view, an equal amount of inoculum, taken from the growing edge of the culture of *A. nidulans*, was introduced into fruits at three depths in the laboratory: (i) just below the green skin, (ii) at a depth of 5 mm. and (iii) on the stone.

For the last two sets, a method suggested by Granger and Horne (1924) was used, whereas for the first, a small peeling of the green skin was taken out by means of a sterile scalpel on three sides. After inoculation of the fungus, the peeling was replaced and sealed with wax. 22 Fruits were employed for each set. The fruits were examined after 2 weeks, the diseased part scraped out and weighed, eliminating



Text-figs. 1–8. Demonstrating the course of the infecting hypha of *A. nidulans* and its mode of perennation. Fig. 1. Long germ tube from the conidium creeping along the cuticle, × 620. Fig. 2. Germ tube entering the cuticle, × 780. Fig. 3. Infecting hypha taking a turn when comes near the epidermis, × 620. Fig. 4. Subcuticular hypha, × 620. Fig. 5. Conidium in the substomatal cavity, × 780. Fig. 6. Hypha in *a.* substomatal cavity and *b.* the subcuticular region, × 780. Figs. 7 and 8. Hyphæ in *d.* ducts and *e.* a cell of the outer mesocarp of the fruits before removal for ripening.

the dead tissues produced due to the operation. A summary of the results is presented in Table VIII.

TABLE VIII

The differential rotting when an equal amount of inoculum is put at different depths in the fruit

Place of inoculum	Wt. of the fresh tissue used for inoculation in gm.	Wt. of the tissue 2 weeks after inoculation in gm.	Wt. of the diseased tissue in gm.	Average wt. of the diseased tissue in percentage
1. Under the green skin ..	2936·5	2239·4	8·0	0·3
2. Depth of 5 mm. ..	2842·5	2265·6	166·4	7·3
3. Just above the stone ..	3410·4	2664·4	382·5	14·3

An examination showed that even allowing slight positional differences there was practically no rotting when the inoculum is introduced just below the green skin, the maximum being in cases where the inoculum reaches the stone. Thus in fruits of the first set only 8·0 gm. of the rotten tissue was obtained in 2239·4 gm. of the tissue used for inoculation. In the second and the third sets 7·3% and 14·3% of the diseased tissue was isolated respectively.

It, therefore, becomes clear that different tissues in the fruit show different degrees of resistance to the fungus and the amount of rot will depend on the depth the fungus is able to traverse before being picked for ripening. The resistance is highest near the epidermal region and decreases with the increase in depth. The epidermis and the outer mesocarp offer considerable resistance whereas the deeper tissues (middle and the inner mesocarp) are more susceptible, favouring the lateral spread of the fungus. If the fungus does not cross the limits of the green skin (outer mesocarp), it will only produce superficial lesions. In order that the fungus may produce the rot in the inner mesocarp, it must overcome the resistance of the external layers and then penetrate into the deeper tissues. Under low conditions of resistance the hyphæ penetrate the epidermis, grow into the outer mesocarp and involve its ducts and cells. This differential reaction of the tissues, thus is of considerable significance in storage. The amount of inoculum may also play an important part in initiating the rot in the living tissue, but a certain minimum number of hyphæ may be required for the purpose.

DISCUSSION

Considerable amount of work has been done on latent infections both outside and in India. Shear and Wood (1913) found dormant infections of *Colletotrichum* and *Glomerella* in the leaves, stems, flowers and fruits of many plants. Dastur (1919) showed that *Glœosporium musarum* is present as latent infection in immature bananas. Wardlaw (1931) confirmed Dastur's observations. Wardlaw and Baker (1926)

demonstrated the presence of *Colletotrichum Glœosporioides* in green mangoes. Baker and Wardlaw (1937) have proved that several fungi are of common occurrence in the tissues of tropical fruits and by the time they are harvested they contain latent infections of several fungi. Baker (1938) made a survey of the organisms which may occur as latent infections during the development of the tropical fruits and drew a relation between the latent infecting fungi, the organisms present on the general surface of the fruits and in the orchard. Sinha (Unpublished) traced the origin of some of the diseases in storage to the infection in the orchard.

A comparative study of the number and the concentration of orchard fungi during various periods in the mango season yielded as many as 13 strains. Some of them (*Aspergillus nidulans* and *A. niger*) were present always, others like *Aspergillus* sp., *Penicillium* sp. and *Rhizopus arrhizus* occurred only occasionally. The relative concentrations of the strains were also found to vary with time but as the factors operating in an orchard are many and variable, it was not possible to draw any general conclusion. Baker (1938) obtained a considerable amount of saprophytic fungal flora in the grape fruit orchard and from the studies extending to nearly one year concluded that the modifying effect of the season on the constituent members of this flora is negligible.

Sinha (Unpublished) isolated only 5 fungi from the surface of mangoes stored in market. Surface washing of Khajli and Phajli fruits, gathered directly from the orchard, have given 9 fungi, some of them are common with those obtained by Sinha. *Neocosmospora vasinfecta* reported by Sinha was found to be absent in these mangoes.

Since the atmospheric flora differs from place to place, different latent fungi are expected under different conditions. Baker and Wardlaw (1937) and Baker (1938) obtained *Colletotrichum Glœosporioides*, *Phomopsis* sp., *Dothiorella ribis* and *Guignardia* sp. as latent infections in green mangoes. Sinha (Unpublished) could recover 4 strains under Lucknow conditions—*Colletotrichum capsci*, *Aspergillus nidulans*, and two sterile strains. In the present investigations five fungi, viz., *Aspergillus nidulans*, *A. niger*, *Fusarium* sp. 1, *Alternaria* sp. and *Acrothecium* sp., were obtained from the Khajli and Phajli varieties. The three fungi of relatively greater importance are *A. nidulans*, *A. niger* and *Fusarium*, *Fusarium* being mainly isolated from the unfertilised and fertilised ovaries. Baker (1938) explained the occurrence of *Fusarium* by the fact that it possesses resistant spores, sometimes capable of withstanding the surface sterilisation technique.

The superficial fungi and those obtained in the atmosphere of the orchard are found to be related to the latent infecting ones. The five fungi, recovered from the apparently healthy fruits, are in common with the 9 obtained as superficial isolates and the 13 collected from the orchard during various periods of the mango season.

Baker and Wardlaw (1937) and Baker (1938) showed latent infections in the fruits of all sizes and proved that in many instances these latent infections are established shortly after the fruits are set. Baker,

Crowdy and McKee (1940) stated that the young mango fruits are readily infected as compared to the old ones, the infection reaching the maximum intensity when the fruits are about half developed. The results of the investigations embodied here reveal that latent infections are definitely related to the age of the mango fruits. They are more susceptible to *A. nidulans* during the earlier stages. The older ones, either are incapable of being infected or are much more resistant. Even by spraying a concentrated suspension of spores of *A. nidulans* no appreciable increase in the latent infection has been found in the fruits of medium and large size. The maximum period of susceptibility lasts till the fruits are about 70–80 mm. in length. Experiments with the isolation of the fungus in question from apparently healthy fruits also support the above observations for the stage of isolation and the stage at which artificial infections are possible are more or less the same. Further, the observations indicate that the amount of infection is directly related to the concentration of the respective fungi on the surface of the fruits and in the atmosphere of the orchard provided the fruits are at the susceptible stage.

A certain amount of work has been done on the mode of perennation of the latent fungi and the histological changes associated with it. Kidd and Beaumont (1925), during the course of their study with storage diseases of apples, came across spores that remained on the general surface of the fruits and in the lenticels until such a time as they were able to germinate and enter the tissues. Horne and Palmer (1935) showed that *Dothiorella ribis* enters the young lenticels of immature avacado pears on trees and forms the mycelium which remains dormant in the air spaces until the fruit is becoming senescent in storage. The present investigations show that while in most cases the conidia are abundantly present and remain quite firmly lodged on the general surface of the fruits, in two preparations the conidia of *A. nidulans* and the hyphæ produced from them were found in the substomatal cavity. Of more common occurrence is a hypha of limited growth (presumed to be of *A. nidulans*) in the subcuticular region.

Regarding the mechanism and the nature of latent infection Wardlaw, Baker and Crowdy (1938) have shown the infection of papaw fruits through the stomata at any stage, at a temperature of 80°–90°, in a saturated or nearly saturated atmosphere. Baker, Crowdy and McKee (1940) showed that for successful infection of the mango fruit by *Colletotrichum Glœosporioides* and allied fungi, an initial period with relative humidity at or near the saturation point, was necessary and this period need not persist for more than 12 hours provided the fruits are not subjected to abnormally dry conditions. The conidia of *A. nidulans*, the fungus in the present study, germinate in a few hours and cause an entry in less than 24 hours. Though the spores are present on the general surface, around and on the lenticels and stomata, they pierce through the cuticle. The fungus, in the ordinary course, unlike *Botryodiplodia theobromæ* (Baker and Wardlaw 1937), is not a wound infecting one though its presence does ensure the entry. There is no structure comparable to the appressorium developed as is found in *Colletotrichum* (Dey, 1919 and Simmonds, 1941). The

entry of the fungus into the epidermal tissue by puncturing the cuticle probably explains the fact that latent infection occurs mostly during the early stage of the development of the fruits. It is probable that due to changes in the cuticle in more mature fruits the infected hyphæ are unable to puncture and gain an entry. The infecting hyphæ after making a puncture in the cuticle remain in a subcuticular position similar to *Colletotrichum* and *Glœosporium* (Simmonds, 1941) and unlike *Colletotrichum lindemuthianum* (Dey, 1919) where the mycelium penetrates the cuticle and persists in the epidermal cells. The artificially infected fruits while on trees do not exhibit any anthracnose lesions but in the laboratory experiment, small orange coloured areas developed at places where the fungus made its entry.

The subcuticular hypha is believed to be the form in which the fungus survives the period of latency. It remains in a latent state for about two months and starts its spread just before the fruits are picked for storage.

The different tissues in the fruit show different degrees of resistance and the amount of rot will depend on the depth the fungus is able to traverse before being picked for ripening. If the focus of infection is deep down into the tissue (inner mesocarp) the greater will be the rot produced. The fungus must cross the limits of the green skin to produce its full pathogenic effects otherwise it will only produce superficial lesions not involving deeper tissues.

The absence of active parasitism during the earlier stages can be attributed to several factors either acting singly or in combination. Dastur (1919), Ghatak (1938) and Baker *et al.* (1940) maintain that the chemical constitution of the fruit is chiefly responsible for this behaviour. Simmonds (1941) who is more definite attributes it to the fact that the upper cellulose layer acts as a barrier which the parasite is unable to overcome owing to its chemical nature or the constitution of the cell-sap and the later advance is facilitated by the withdrawal of the toxic substances due to an increase in the enzyme action or by alterations in the cell-sap. The present investigations show that the innermost cuticular layer, which is characterised by its being denser and at times yellower, offers considerable resistance to the invading organism, thereby arresting its further advance, the degree of resistance determining the position taken by the subcuticular hypha—either directly above or even slightly raised above the epidermal cells. Later advance, which in most probability is brought about the time of picking, is initiated by the weakening of the lower tissues due to various physical and chemical changes associated with growth and senescence of the fruits.

Summary

The paper deals with the investigations on the latent infection in the mango fruit using two varieties—Khajli and Phajli.

Thirteen fungi were found to occur in varying concentrations in the atmosphere of the orchard, of which nine strains were common with the fungi obtained from the general surface of the fruits. Some

of these have been noticed to occur throughout the mango season, some quite frequently and still others only rarely.

Five different fungi have been isolated as latent infections from the unfertilised ovary to the mature fruit before the time of picking. Some of these have been isolated more frequently than others. All the latent fungi are common to those found on the general surface of the fruit and in the orchard under natural conditions.

Two methods, *viz.*, spray of a concentrated conidial suspension and an application of conidia on the superficial wounds have been used to cause latent infections artificially by *A. nidulans*.

Younger stages (below 75 mm.) are more susceptible, the resistance of the fruits increasing with the advancement in maturity.

Investigations include observations on the mode of perennation of the fungus during the period of latency. The conidia are abundantly present on the general fruit surface and some of these remain quite firmly lodged. Germinated and ungerminated conidia were also detected in the substomatal cavity. A more common method of perennation is a hypha of limited growth (presumed to be of *A. nidulans*) that remains dormant in the subcuticular region.

The hypha gains an entry into subcuticular region by piercing through the cuticle. The course of the infecting hypha has been demonstrated.

The subcuticular hypha remains dormant for about two months, till the fruits are on trees and it is believed that this hypha resumes its activity a little before the fruits are picked, and reaches its maximum when the fruits are in storage.

Different tissues of the fruit have been found to behave differently. The epidermis and the outer mesocarp offer considerable resistance to the organism whereas the deeper tissues are more susceptible favouring the lateral spread of the fungus. The amount of rot depends on the depth the fungus is able to traverse before being picked for ripening. If the fungus does not cross the limits of the green skin it will only produce superficial lesions.

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* Not seen in originals.

THE STATUS OF *DESMOTRICHUM* Bl. AND THE SYNONYMY OF *DENDROBIUM MACRAEI* LINDL. AND *DESMOTRICHUM FIMBRIATUM* Bl.

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Some of the South Indian sheets of *Dendrobium Macraei* Lindl., belonging to Sibpur Herbarium, were some years ago re-identified at Kew as *Desmotrichum fimbriatum* Bl. The late Father Blatter has also similarly reidentified a Bombay sheet of *Dendrobium Macraei* Lindl. of Sibpur Herbarium as *Desmotrichum fimbriatum* Bl. Further they relegated *Dendrobium Macraei* Lindl. to the role of a synonym under *Desmotrichum fimbriatum* Bl., apparently on grounds of priority. These changes in the nomenclature of these species have now been included in Gamble's *Flora of Madras* and in Blatter's *Revision of Cooke's Flora of Bombay*. The writer, however, has been unable to accept their conclusions, namely, (1) the reduction of *Dendrobium Macraei* Lindl. to a synonym of *Desmotrichum fimbriatum* Bl. and (2) the revival of *Desmotrichum* Bl. once again to the rank of a valid genus for a group of orchids originally segregated from *Dendrobium* Swartz.

1. Dendrobium Sw.

Olaf Swartz was the author of the genus *Dendrobium*, who, in 1799, gave this name to a group of epiphytic orchids (from *dendros-arbor* and *bios*-life). He created the genus out of a section of Linnaeus's Epidendra, where the lateral outer perianth lobes (tepals) were united with the labellum round its base and produced into a horn-shaped mentum or sac. In typical *Epidendrum*, the tepals are free and spreading, but do not form a horn-shaped mentum. The *Epidendrum* of Linnaeus was originally a heterogeneous group, including under it several clearly definable genera. Olaf Swartz was the first to recognise this fact and he split it up into several distinct but smaller genera. One of these was *Dendrobium*. In 1799, he defined it thus, "petala 5, erecto-patentia lateralia exteriora antice circa basin labelli conniuentia vel connata, saepe cornumentientia. Semina priorum. Genus labello a petalis later, exterioribus antice productis basi incluso, ab. Epid. and Cymb. distinctum". Following this brief description, he described several species which were grouped together under (1) *Acaulia*, (2) *Caule unifolio* and (3) *Caule foliosa*. In 1805, he amplified the generic characters of *Dendrobium* slightly and also referred to a drawing of a typical flower of *Dendrobium*.

2. Desmotrichum Bl.

In 1825, C. L. Blume published his *Desmotrichum* in the Bijdragen. He based it on certain species of *Dendrobium* of Swartz, the chief character on which he based his new genus was the "anthera gynostemium terminans, denti dorsali affixa cucullata (., unde nomen generis) dorso carnoso bilocularis". Besides elaborating the floral characters, he also described in detail the vegetative characters. But a comparison of the species redescribed under his *Desmotrichum* and the same described originally under *Dendrobium* Swartz leaves the impression on the mind that there are not enough points to distingiush the two genera from each other.

In 1830, John Lindley stated that the most genuine form of *Dendrobium* was no doubt that having caulescent stems with fascicles or racemes of membranous coloured flowers, though there were insensible gradations from that, into rhizomata having false bulbs. He further considered that Blume's genera (*Desmotrichum, Onychium*, etc.), which he reduced to *Dendrobium*, had no characters to distinguish them.

L. Blume seems to have accepted this view-point of Lindley *in toto* and accordingly in 1836, he reduced his *Desmotrichum* to *Dendrobium* Sw., because, in his 'Rumphia', he has enumerated under "Rudera Bojora", the following species of *Dendrobium*: *Dendrobium crumenatum* Sw. [*Dendrobium* (*Onychium*) *crumenatum* Bl.], *Dedronbium* (*Desmotrichum*) *fimbriatum* Bl., *Dendrobium* (*Desmotrichum*) *appendiculatum* Bl., and *Dendrobium* (*Desmotrichum*) *convexum* Bl. In 1848, Blume however, removed, unquestionably, all doubts regarding the status of his *Desmotrichum*, as he now definitely relegated it to the role of a synonym under *Dendrobium*. Hasskarl, Dalzell, Miquel, Reichenbach. f., Dalzell and Gibson, Walpers, Thwaites, Bentham and Hooker. f., Pfitzer, J. D. Hooker, Grant, Ridley, King and Pantling, G. A. Gammie, Oakes Ames and J. J. Smith, who came in the wake of Lindley and Blume, did not think it justifiable to revive *Desmotrichum* Bl. to generic rank again. It therefore remained unheard of and in the position of a synonym till 1910, when Dr. Kranzlin once again raised it to the rank of a genus (in Engler's *Das Pflanzenreich*).

In 1896, Mr. H. N. Ridley proposd to retain the old name of *Desmotrichum* Bl. to the section *Cadetia* of Hooker's *Flora of British India*. He contended that the section *Desmotrichum* was a distinct one in possessing usually, a creeping primary stem, which was sometimes elongate and sometimes short, but which in any case, threw up many slender polynodal stems, which branched again and again and each branch terminated in a terete or flattened psedobulb, composed of one, rarely two, internodes and bearing a single (and only exceptionally a second) leaf.

Dr. Kranzlin's (1910) reasons for reviving *Desmotrichum* Blume to generic rank are not convincing though he claims that the characters of *Desmotrichum* as emended by him along with its characteristic habit and the extraordinary flowers were sufficiently natural to form a separate genus.

Dr. Kranzlin classified the two genera as :—

A. Caules multi-articulati, rhizoma breve.

a. Sepala lateralia cum pede gynostenii mentum formatian, labellum ecallosum v. ut plurium lineis præditmum...... *Dendrobium* Sw.

B. Caules uni-rarius (bi)-articulati, rhizoma longe repens.

(*a*) Labellum trilobum raceme pseudo-terminalis Flores mediocres v parvi, epimeri, labellum sæpius antice flabellatum v pilosum ....*Desmotrichum* Bl.

The main points of difference relied upon by him between the two genera are therefore short rhizome and multi-articulate stem in *Dendrobium* and long rhizome and uni- or rarely bi-articulate stemin *Desmotrichum*. In other respects, they almost agree with each other. The following species of *Desmotrichum* Bl. described by Kranzlin throw some interesting light on the genus and its true position. (1) *Desmotrichum angulatum* Bl. is "Caules fasciculati, basi ramosi teretes, supra compressi, pauci pluri-articulati". (2) *Des. criniferum* (Lindl.) Kranzlin is "Caules ramosus nitidus, multi-articulatus". (3) *Des. scopa* (Lindl.) Kranzlin is "Caules penduli teretes compressiusculive sulcati *multi-articulati*". (4) *Des. parietiformi* (J.J.SM.) Kranzlin is Caules ramosi *mutti* articulati. (5) *Desedurm* (J.J.SM.) Kranzlin "caules penduli ad 40 cm. longi ramossimi', in nodis radicantes oblique fibrallis foliorum venustiorum obisit *multi-articulati, articuli* (-12). (6) *Des. bancanum* (J.J.SM.) Kranzlin is "rhizoma breve" (see *Dendrobium*). (7) *Des. fimbriatum* Bl. is "sympodia polycladia, pendula 60–90 cm. longe, ramuli tenues, pluri-articulati". (8) *Des. Kunstleri* (H.f.) Kranzlin is "caules longissime repentes, multi-articulati". The above species of *Desmotrichum* are either pauci multiarticulati or multi-articulati. One of them has also a short rhizome as in *Dendrobium*. The above species definitely show that they cannot be made to fit in with the chief diagnostic distinction of *Desmotrichum*, namely, "caules uni rarius bi-articulati' and rhizoma 'longe repens' ascribed by Kranzlin in the generic key, quoted on previous page. The generic distinction breaks down undoubtedly.

Ridley (1924) differentiated *Desmotrichum* Bl. from *Dendrobium* Sw. by the former possessing a **profusely branching stem** with **one** or **two** flowers, and by the latter having **unbranched** stem with a **raceme** of flowers. This is, however, no better than Kranzlin's. An examination of his Flora gives the following additional information about the genus *Desmotrichum* Bl. *Den. serra* Lindl., *Den. rosellum* Ridl., *Den. lobatum*, *Den. atro-rubens*, *Den. prostratum*, *Den. villosulum*, *Den. crumenatum* and *Den. pandanete* have all got branching stems and *Desmotrichum laciniosum* has a raceme of flowers. Here again it becomes clear that the generic limits assigned to *Desmotrichum* by this author have also proved unstable.

On p. 1400 of Gamble's *Flora of Madras*, Vol. VIII (1928) under synopsis of the genera, the following characters are assigned to each genus :

Rhizome long, annulate, stem nodose, bearing uninodal pseudobulbs, ...(4) *Desmotrichum.*

Rhizome short stemless, with a single pseudo-bulb or pseudobulbs plurinodal.....(5) *Dendrobium.*

On p. 1412 of the same work, *Dendrobium* is described thus :—"Stems elongate, nodose or of pseudo-bulbs, pseudo-bulbs basal or on the stem, uni or plurinodal". What has been stated in the Key appears to have been contradicted afterwards, and the differences that were supposed to exist between the two genera have been compounded. The genus *Dendrobium* as described on p. 1412, clearly accommodates *Desmotrichum* within it. In the *Revision of Cooke's Flora of Bombay*, it is said that what has hitherto been known as *Dendrobium Macrei* Lindl. has now been renamed *Desmotrichum fimbriatum* Bl. In addition to this reduction, *Dendrobium Kunstlei* H.f. has also been reduced to *Desmotrichum fimbriatum* Bl. by the author of this revision, which however is kept separate under the new combination *Desmotrichum Kunstleri* (H.f.) Kranzlin, in the Pflanzenreich.

From what has been said above, it is easy to infer (1) that Kranzlin, who revived *Desmotrichum* Bl. to generic rank, in spite of the verdict of Blume, Lindley and a score of other orchidologists up to R. Schlecter of recent times, to the contrary, has been unable to restrict his new combinations within the bounds of the genus thus revived, and (2) that the authors of the *Flora of Malay Peninsula, Flora of Madras* and the *Revised Flora of Bombay* shared similar experiences of transgressing the limits of the genus, defined by them. Therefore, these indisputable facts would drive home to any one the conclusion that *Desmotrichum* Bl. cannot secure the status of an independent valid genus, with clear-cut characters, superseding *Dendrobium* Sw. even for such of the species as have been placed under it by Kranzlin and his followers. Its status is rather very dubious and does not deserve even that of a minor sectional rank. It has therefore been found that *Desmotrichum* Bl. should now revert to the obsolete position to which Lindley and Blume relegated it in the middle of the last century. J. J. Smith, Elmer D. Merrill and Schlecter have retained *Dendrobium* to which *Desmotrichum* Bl. has been reduced.

DEN. MACRAEI LINDL.

Dendrobium Macræi was described by Lindley in 1840, who based it upon a Ceylon sheet and on the drawings of Macrae. He described it as "Caules longe articulis brevibus sertulariæ ad instar. Pseudobulbi lutei teretis apice viridis fusco-lutescentes. Labello trilobo lobo medio crenato-plicato marginibus recurvus. . . .This curious species is covered with clavate spurious bulbs, from the apex of which springs a solitary oblong leaf, producing from its axilla 2–3 snow-white flowers. I only know the latter from Mr. Macrae's drawings." When, in 1859, he reduced Dalzell's *Den. nodosum* to *Den. Macræi*, he made the following additional remarks about his Ceylon species, that though at first, the flowers were described to have an entire lip, upon the faith of a Singalese native drawing, but it was doubtful, whether such was really

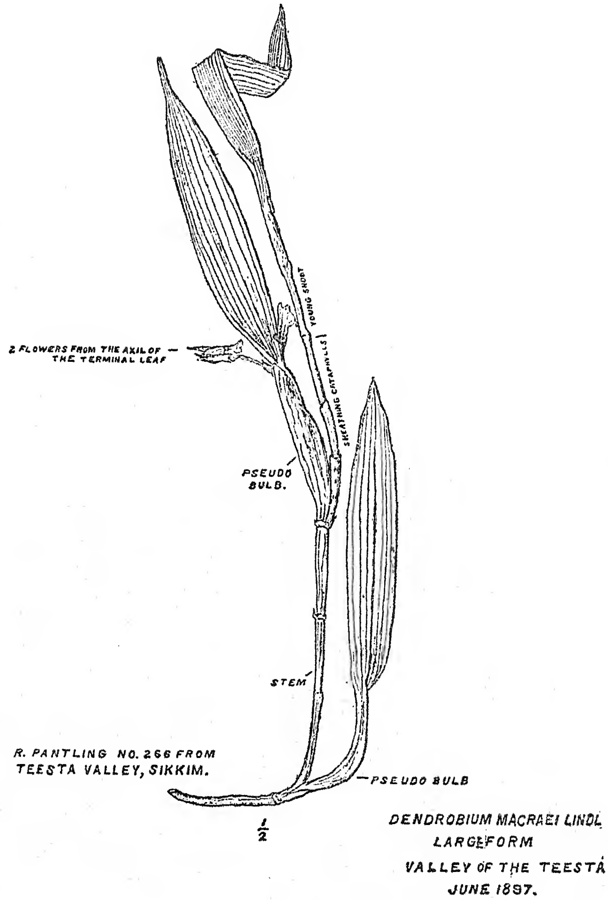
their structure, as Dalzell's *Den. nodosum* was undoubtedly the same as *Den. Macræi*, and an examination of Dalzell's sheets showed the flowers to have " labelli trilobi, lobo intermedio apice lateraliter valde dilatato plicato emarginato ". *Den. nodosum* Dalz. was the first of the synonyms under *Den. Macræi* Lindl. Sir J. D. Hooker described *De . Macraei* as having fusiform pseudo-bulbs, short conic mentum ; side lobes of lip, oblong obtuse ; mid-lobe small, with two small diverging lobules crenulated and crisped. King, Gammie and Cooke agreed with Hooker in their description of the mentum and the lip of *Den. Macraei.* They also agreed with Hooker in reducing *Den. Rabani* Lindl., *Den. pardalinum* Reichb. f. and *Desmotrichum fimbriatum* Bl. to *Den. Macraei* Lindl.

DES. FIMBRIATUM Bl.

Desmotrichum fimbriatum Bl., a Javanese species, was transferred in 1830 by Lindley to *Dendrobium* and recombined as *Dendrobium fimbriatum* (Bl.) Lindl. He described it as "bulbis monophyllis ovalis oblongis compressis, foliis oblongo-lanceolatis obtusiusculis, floribus subsolitarius, labello limbo dilatato, bifido-plicato". This is more or less a copy of Blume's description of *Desmotrichum fimbriatum* Bl. Lindley detected subsequently, that the name *Den. fimbriatum* was already occupied by another valid species, and he therefore renamed *Des. fimbriatum* Bl. in 1840 as *Dendrobium plicatile.* In 1857, while working out Zollinger's collection of Java orchids, Reichenbach. f. identified Zollinger's no. 1294 as *Desmotrichum fimbriatum* Bl., which he renamed as *Dendrobium flabellum* Reichb. f., without evidently knowing that Blume's species had already been renamed by Lindley first in 1830 as *Dendrobium fimbriatum* Lindl., and later in 1840 as *Dendrobium plicatile* Lindl. In 1874, he also created two species, apparently from *Desmotrichum fimbriatum* Bl. for one of which he retained his original name of *Den. flabellum*, including, under it as a synonym, the Blumean species, with, of course, a mark of interrogation before it. To the other species, he gave the name of *Den. Binnendijkii.* Fig. 7, pl. 118 is cited by him under *Den. flabellum* and fig. 6, pl. 118 is cited under *Den. Binnendijkii.* Fig. 7 is the tip of the labellum with the two lower side lobes and fig. 6 is also a picture of the lip with the mentum, lower lateral lobe and one half of the upper or mid-lobe with the deep crenations shown. There is practically no difference between these two bits of figures and both of them can safely be united together under *Den. flabellum*, the earlier of the two names. *Den. flabellum* Reichb. f. becomes therefore synonymous with *Den. plicatile* Lindl.

According to Lindley, *Den. Macraei* differs from *Den. plicatile*, in (1) possessing a terete pseudobulb, (2) in having 2 or 3 snowy-white flowers in the axil of the solitary leaf and (3) in having the mid-lobe of the labellum crenato-plicate at the margin, whereas, according to him, *Des. fimbriatum* Bl. has an oblong compressed pseudobulb, solitary axillary flower and a bifid mid-lobe with crenate plicate margins in the labellum. He has, however, omitted one very important point which more than anything else differentiates the two species quite markedly. It is the shape of the mentum or the spur. Mr. J. J. Smith has made this feature of the flower as the chief deciding character in separating the

two species, which have so long been held to be the same. In *Den. Macraei*, the mentum is broad sac-shaped and forms with the ovary a right angle, whereas in *Den. plicatile* (*Den. flabellum* Reich. f. apud J. J. SM) the mentum is thin sac-shaped and forms with the ovary an acute angle. Mr. Smith has examined Blume's types of *Des. fimbriatum* in the Leiden Herbarium and has recorded his opinion that they are



DENDROBIUM MACRAEI LINDL.

Fig. 1.

really Blume's *Des. fimbriatum*, though devoid of flowers. Hooker included *Des. fimbriatum* Bl. as a synonym of *Den. Macraei* on the ground that he failed to find any characters whereby he could distinguish the

latter from the former. But the results of the author's examination of the cotype sheets in the Sibpur Herbarium agree with those of Mr. Smith and the differences in the shape of the mentum observed by us quite easily separate one from the other (*vide* Figs. 1 & 2 and 4 *a* & *b*). Mr. Smith, however, retained *Den. flabellum* Reichb. f. for *Des. fimbriatum* Bl. when there was already an earlier name in *Den. plicatile* Lindl. to it. But as the former names are not sustainable under the rule of priority, they should give place to *Den. plicatile* Lindl.

In 1905, Mr. Oakes Ames described *Den. Macraei* Lindl. and reduced *Den. flabellum* to it. In 1908, he identified a Philippine plant as *Den. Macraei* and gave an enlarged synonymy under it. He included therein, besides others, *Den. Kunstleri* H.f. and *Des. fimbriatum* Bl. The geographical distribution of *Den. Macraei* was also considerably extended as far as Perak, Singapore, Borneo and Java. In 1915, however, he recognised his former error and re-identified the Philippine plant as *Den. plicatile* Lindl. and remarked that there were very slight differences between *Den. plicatile* and the Buitenzorg specimen called by J. J. Smith as *Den. flabellum*, which were too inconsequential for specific differentiation. *Den. Macraei* is not, therefore, the same as *Den. plicatil* . It does not extend east of India and definitely not as far as Java as mentioned by many. Mr. E. D. Merrill mentioned only *Den. plicatile* Lindl. as occurring in the Philippines and quoted *Den. Macraei* Ames (non-Lindl.) and *Des. fimbriatum* Bl. apud Kranzlin in *Eng. Das Pflanzenreich* as synonyms.

Den. Kunstleri H. f.

Den. Kunstleri H. f. was established by Dr. J. D. Hooker on Scortechini No. 253^{b}* from Perak. He described it as having fusiform pseudobulbs; large elliptic lanceolate acuminate leaves; mentum much shorter than sepals, conic acute; mid-lobe very large quadrate, orbicular, with two crenulate lamellæ on the disk and plaited undulate sides. He also remarked that this species differed from *Den. Macraei* in the much broader larger coriaceous leaves, the acute side lobes of the lip and very large quadrate mid-lobe, which though similarly plaited was not bifid. In 1905, Mr. J. J. Smith reduced this to *Den. flabellum* Reichb. f. on grounds of similarity between them in almost every detail. Since *Den. flabellum* is the same

* Father B. Scortechini has appended a field note to his No. 253^{b}, the type of *Dendrobium Kunstleri* H. f., and it is reproduced here both for record and for future reference. [This is in Sibpur, with the names in Hooker's handwriting.]

253^{b}. Dendrobium. Sect. cadetia. Stems running terete, nodes 1—1½″ apart, with a pseudobulb every 5–6 nodes, pseudobulb elliptic lanceolate 2–3″ by ¾–1″, compressed, 1-foliate leaf, elliptic 8–10 by 2–2½″, coriaceous, longitudinal nerves, faint, base broad, peduncle terminal, 1-flowered with scarious bracts at the base, lateral sepals narrow, lanceolate attached by the oblique long base at the foot of the column, 1¼″ with the foot oblique base by 1/6″, membranous yellowish, mottled dirty purple, veined longitudinally, posterior similar except it has not the oblique base, petals similar to the posterior sepal but narrower. Labellum 3-lobed 1¼″ long, lateral lobes narrower triangular mottled purplish, terminal orbicular, emarginate wavy and plaited, yellowish with the two central lamellae, running from its middle to the base. Pollen masses ovate oblong.

as *Des. fimbriatum* Bl., *D n. Kunstleri* becomes identical with *Des. fimbriatum* Bl. or *Den. plicatile* Lindl.

A comparison of the sheets of *Den. flabellum* Reichb. f. of the Buitenzong Herbarium, Scortichini's No. 253[b], named *De:. Kunstleri* H. f. and Blume's *Des. fimbriatum* in the Leiden Herbarium points to their complete similarity with each other and hence they are all conspecific.

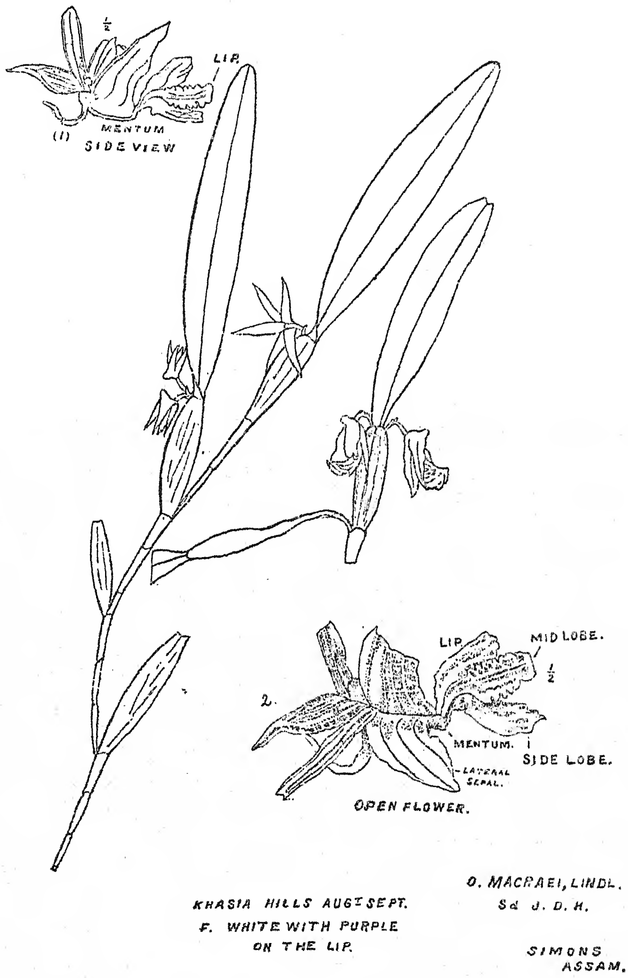


Fig. 2

In 1896, Mr. H. N. Ridley reduced *Den. flabellum* Reichb. f. to *Den. Kunstleri.* In 1907, however, he raised *D n. flabellum*, reducing *Den. Kunstleri* under it like Smith. In 1924, he raised *Des. fimbriatum* Bl. to specific rank, evidently after Kranzlin, and reduced both

Den. flabellum and *Den. Kunstleri* to synonyms under it. But Kranzlin keeps *Den. Kunstleri* separate from *Des. fimbriatum* Bl. under the new combination *Des. Kunstleri* (H.f.) Kranzlin. In *Das Pflanzen eich* Kranzlin has (1) *Des. Binnendijkii* (Reichb. f.) Kranzlin and (2) *Des. fimbriatum* Bl. created apparently out of *Den. fimbriatum* Lindl. and (3) *Des. Kunstleri* (H.f.) Kranzlin from *Den. Kunstleri* H.f. He cites as synonyms *Den. fimbriatum* Lindl., *Den. flabellum* Reichb. f. and *Den. Binnendijkii* Reichb. f. under both *Des. Binnendijkii* (Reich b.f.) Kranzlin and *Des. fimbriatum* Bl. This citation of the same synonyms under two different species is rather unintelligible and creates a very difficult situation. From a scrutiny of (1) the synonyms as found in the *Pflanzenreich* (2) the descriptions of the species and (3) the plate illustrating them, the writer is unable to separate *Des. Binnendijkii* from *Des. fimbriatum* Bl. The synonymy under each in the *Pflanzenreich* appears rather confusing. *Den. Macraei* Lindl. cannot be reduced to *Des. fimbriatum* Bl., for even according to Kranzlin, the mentum in *Des. fimbriatum* Bl. is 'conicum leviter recurvatum fomantia'. In *Den. Macraei*, on the other hand, it is short broad, conic and forms a right angle with the ovary and is not recurved [Figs. 2 (1) and (2)]. The very same points of distinction separate *Den. Macra i* from *Den. Kunstleri* H.f. and unite the latter with *Den. plicatile* Lindl. (*Des. fimbriatum* Bl.).

Fig. 35 A, on p. 355, of the *Pflanzenreich*, purporting to illustrate *Des. fimbriatum* Bl. is far from correct, though the monographer condemns it for the sake of only the lateral instead of the terminal leaves. The species is shown there to be diphyllous, whereas the species in question is typically monophyllous. Fig. 4 *infra* is a drawing of Scortechini No. 253^{b}, the type (cotype) of *Den. Kunstleri* H.f. Fig. 3 is a drawing of Kunstler No. 6897, also named here as *De :. Kunstleri*. If we compare these with *Den. flabellum* Reichb. f., their similarity with one another will become quite evident. In Fig. 4, the labellum as drawn orginally on the left-hand side and from which Hooker described his *De :. Kunstleri* is not its correct form. The exact form of the labellum as made out from a flower on the same sheet is drawn as in Fig. 4 (*b*) on the right. The mid lobe of the labellum is moreover less bifid here (*vide* Hooker's description of it in Icon. No. 2023) and agrees more with Lindley's description of it than with that of Hooker. Fig. 1 is a sketch of King and Pantling's No. 266 and Fig. 2 is a drawing of Simon's Sheet from Assam, named by J. D. Hooker as *Den. Macraei* Lindl. These sheets have been quoted under *Desmotrichum fimbriatum* Bl. by the author of the *Pflanzenreich*, who merged *Den. Macraei* with it. But the differences between these two species will become clear when Figs. 1 and 2 are compared with 3 and 4, especially the flowers in each case.

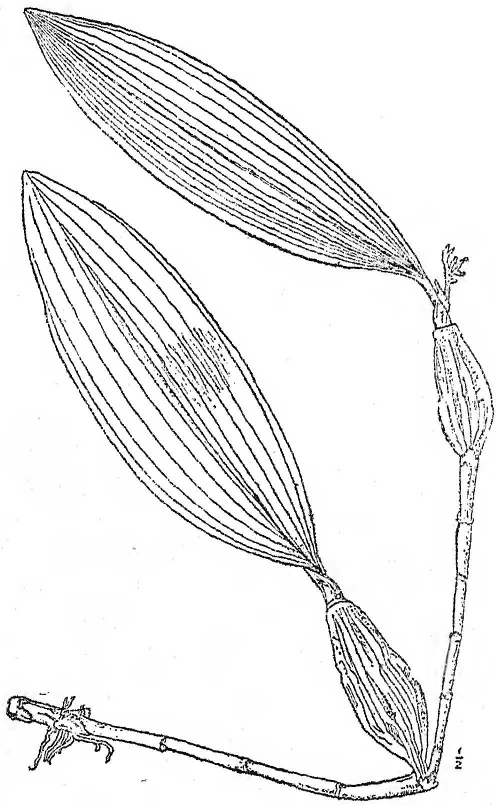
Therefore there seems no justification in reducing *Dendrobium Macraei* Lindl. to *Desmotrichum fimbriatum* Bl., as both are perfectly distinct species, differing from each other in a remarkable manner. *Dendrobium Kunstleri* is not materially different from *Desmotrichum fimbriatum* Bl. as shown above. It is, therefore, synonymous with *Des. fimbriatum* Bl. Since *Des. fimbriatum* Bl. has been renamed as

Den. plicatile Lindl., *Den. Kunstleri* H.f. also becomes a synonym of *Den. plicatile* Lindl.

Descriptions of the genus *Dendrobium* and of the two species discussed above are given below.

DENDROBITM SWARTZ

Orchids, epiphytic on forest trees, sometimes rhizomate, then rhizomes simple or branching with pseudo-bulbs simple, few or many nodal ; sometimes caulescent, caules short or long, cæspitose, simple branching and erect, creeping or pendulous, with sheathing cataphylls which when old lose their shape and look like fibrous threads at the nodes. Leaves one, two or many, either throughout the stem, then bifarious, or at the tips of the pseudo-bulbs then either one or two. Flowers solitary, fascicles or racemes, from the axils of the leaves or



KING'S, COLLECTTOR (H.KUNSTLER)-
NO.6897 FROM PERAK. NAMED D.KUNSTLERI H.F.

Fig. 3

from among the scarious cluster of bracts at the tips of the pseudobulbs. Tepals 5, narrow, erect and spreading, white or cream coloured, sometimes speckled red, two outer larger, the so-called sepals, united with the base of the labellum or lip and produced along the foot of the column to form a short conical mentum which is either obtuse or acute, thin or broad, straight or recurved. Labellum articulate with the foot of the column or connate, rarely sessile, tip entire or three-lobed and variously marked. Creamy or yellow, speckled pink or red at base. The colour of the lip is variable. Anthers bilobed, within the acute tips of the colum, Pollinia 4 in collateral pairs.

Difference in vegetative parts sometimes afford good sectional characters. The shape of the lip and the mentum afford good points of specific differentiation.

Mentum short, blunt and forms a right angle with the ovary. (1) *D. Macra i.*

Mentum long, narrow and forms an acute angle with the ovary. (2) *D. plicatile.*

(1) ***Den. Macraei***, Lindl. *Gen. and Spec. Orch.* (1830) 75 : *J. L S.* 111, 6 ; *Thw. Enum.* 297 ; *Dalz. and Gibs. Bomb. Fl.* 260; *Hook. FBI. V.* 714 ; *King and Pant. Orch. in A.R.B.G.C. VIII*, 61, *t*, 86 ; ***Dendrobium nodosum***, *Dalz. JOB, IV*, 292 ; *D. Rabani, Lindl. in J.L.S., III*, 7 ; ***D. Pardalinum***, *Rchb. f. Gard. Chron.* (1885) *II*, 230.

Epiphytic on trees, stem long, creeping, annulate, radiciform profusely branching, branches polynodal, smooth, shining, yellowish brown, terete, strongly coriaceous, each branch ending in a pseudobulb, 1–3 inches long, linear, fusiform or clavate, nitidus, flavidus or yellow brown, terete, compressed sulcate when dry. Young shoots cataphyllous, cataphylls drop off when mature, leaving fibrous threads at axils. Leaf solitary at tip of pseudobulb ovate lanceolate or oblong elliptic, acute or obtuse, coriaceous. Flowers one or two from within scarious bracts at tip of the pseudobulbs, small, 1–1½ in diameter. Lateral sepals larger ovate acute attached to the long foot of the short cloumn and forms a short blunt mentum which is erect and forms a right angle with the ovary. Petals smaller, narrower lip jointed to the foot of the column and enclosed within it in bud, obovate three lobed, side lobes membranous, as long as the mid lobe or slightly shorter than the midlobe, midlobe obovate, truncate with two lamelleæ running down the centre up to the base, much plicate along the upper margins, cream yellow. King and Pantling's drawing of the labellum differs in shape from that observed by me from one of the flowers of Pantling's sheet No. 266. Column short, margins toothed, anther attached to the column and in bud covers the tip of the column like a lid. Fruit 1–1·25 long. Flowering in May.

In hot moist tropical valleys of Sikkim Himalayas, Pantling 266, Gamble 9649 ; Assam, Simons, plate only ; Jaintia Hills, King's collector without No. ; Upper Burma, Abdul Hak ; Nilgiris, Thomson ; Concan, Stocks ; Mahabaleshwar (cultivated) H. E. James ; Botanic Garden, Calcutta (cultivated). It is said to be quite common on the

Western Ghats and in the Central Province of Ceylon, wherefrom the type of the species was collected, drawn and described.

The Mahabaleshwar specimen looks somewhat different from the rest. The mid lobe of the lip is broad and spreading at the top on the two sides.

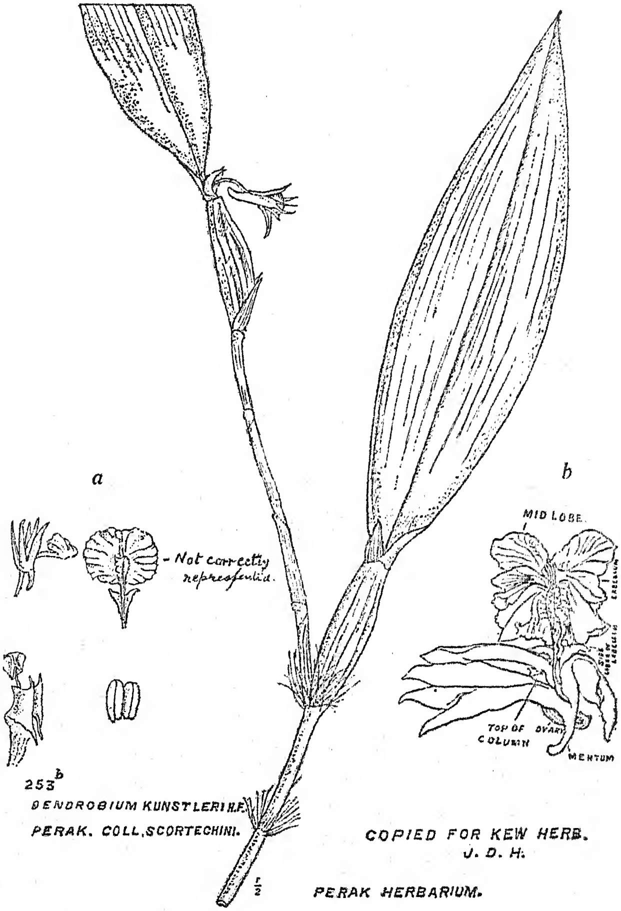


Fig. 4

(2) *Den. plicatile*, Lindl. in Bot. Reg. 26 (1840) Misc. 10; Rchb. f. in Walp. Ann. 6 (1861) 307; Naves Novis App. (1882) 234; Ames Orch. V. (1915) 132; Enum. Phil. Pl. I (1924) 353; *Den. Binnendijkii*, Rchb. f. in Xenia. Orch. II (1874) 74, t. 118, f. 6; *Den. flabellum*, Rchb. f. Bonpl. V (1857) 56; Xen. Orch. II, 75, t. 118. f. 7; Ridl. Mat. Mal. Fl. Monocot. (1907) I, 36; J. J. Smith Orch. Java. (1905), 315; *Dendrobium fimbriatum*, Lindl. Gen. and Spec. Orch. (1830), 76; Miq. Fl. Ind. Bat. III (1855), 635; Den. Kunstleri, H. f. FBI. V (1895), 714; Ic. Pl. t. 2023 (1892); Ridl. in J.L.S.B. XXXII (1896), 239; *Desmotrichum*

fimbriatum, Bl. Bijdr. I (1825), 529; Kranzlin in *Das Pflanzenreich* IV. 50, 11. B. 21 (1910), 354; Ridl. Mal. Fl. V. (1924), 30; Fischer Mad. Fl. VIII (1928), 1412; Blatter Fl. Bomb. in J.B.N.H.S. XXXV (1931), 265; *Desmotrichum Binnendijkii* (Rchb. f.) Kr. L. C. 353; *Desmotrichum Kunstleri* (H.f.), Kr. L. C. 356.

Rhizome creeping, stems branched, cataphyllous, terete below and flattened above where they branch, shining yellow. At every 5–6 nodes and at the flattened tip is a pseudobulb 2–5–3, long, elliptic, lanceolate, compressed, tip broad with numerous scales. Leaf solitary, broad, oblong, elliptic coriaceous, strongly veined, base broad, 8–10″ by 2–2½″. Flowers 1–2, from among the scarious bracts, at tip of the pseudobulb. Sepals narrow, lanceolate, attached to the long oblique base of the column to form an almost straight narrow long (*i.e.*, in a line with the column) mentum, 3/4 to 1 in. long and forms an acute angle with the ovary, membranous, yellowish, mottled dirty purple. Posterior sepal similar with no oblique base. Petals similar to the sepals, but narrower. Labellum 3 lobed, little longer than an inch, side lobes narrow triangular, acute more or less sagittate, mottled purplish, terminal quadrate, deeply plicate and emarginate, with two central lamelleæ running from its middle to the base. The spur is very characteristic in this species, which is long and narrow and forms a very acute angle with the ovary. The lip is also peculiar in being three lobed with the side lobes small, triangular and acute and the central lobe broad quadrate, with deep plications and emarginate tip which will lead one to mistake it to be bifid. I have dissected the flowers from a cotype sheet of *Den. Kunstleri-Den. plicatile*, Lindl. and find that the lip has been wrongly drawn in Fig. 4 (*a*). A correct drawing is shown on the right (Fig. 4 *b*).

Malaya: Perak, Wray 3154; Scottechini 253^b (Type—Calcutta), Kunstler 1877, 6897; Singapore; Changi, Ridley, 1789; Andamans, Davies.

Summary

After a very careful study of the literature bearing on these disputed species and after an examination of the plates and specimens, available in the Sibpur Herbarium, the writer has arrived at these conclusions:—

(1) *Desmotrichum* Bl. may perhaps be retained as sectional name for a very limited group of Dendrobia, consisting usually of a primary creeping stem with several polynodal branches, each branch ending in a monophyllous pseudobulb and with an axillary solitary flower, but it is preferable to sink it under *Dendrobium.*

(2) *Dendrobium* of Swartz is a sufficiently comprehensive genus and also embraces the species described under *Desmotrichum* Bl. There is not much difference to distinguish the latter generically from the former. This view has been accepted by Blume himself and *Desmotrichum* has been included by him under *Dendrobium.*

(3) *Dendrobium Macraei* Lindl. is the valid name for the widely distributed Ceylon species and includes under it and is conspecific

with *Den. nodosum*, *Den. Rabani* and *Den. Pardalinum*. It is entirely different from *Des. fimbriatum* Bl.

(4) *Dendrobium plicatile* Lindl. is the earliest valid name for *Des. fimbriatum* Bl. and is conspecific with *Den. flabellum* Reichb. f. *Den. Kunstleri* H. f., *Den. Binnendijkii* Reichb. f. and *De . fimbriatum* Lindl.

(5) Confusion in synonymy originated in the *Flora of British India*, wherein under *Den. Macraei* Lindl., the following were included, namely, *Des. fimbriatum* Bl., *Den. flabellum* and *De . Binnendijkii.*

(6) In the *Pflanzenreich*, three separate species of *Desmotrichum* were created from the species mentioned in (4) above, to one of which *Den. Macraei* Lindl. was reduced.

(7) In the Indian floras, published subsequent to the *Flora of British India*, the changes introduced in the *Pflanzenreich* were adopted apparently without scrutiny.

(8) *Dendrobium* Sw., *Den. Macraei* Lindl. and *Den. plicatile* Lindl. have been fully described, with notes on distribution and herbarium sheets examined.

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SOME STUDIES ON THE CONDUCTIVITY AND HISTOLOGY OF GRAFTED MANGO SHOOTS

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and

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As a rule mangoes are propagated by the ancient grafting method of inarching with a view to producing plants of the desired quality of fruits. There is, however, a common complaint amongst gardeners that grafted mangoes suffer from high mortality and some of them which survive have retarded growth and also produce shoots and leaves crowded into bunches. The present article embodies the result of an investigation carried out to elucidate the causes, which may be responsible for poor growth and high death rate in grafted plants. Further with a view to reduce death rate of grafted mangoes various experiments were undertaken to improve the technique of grafting. Studies on the histology of graft unions were also made. It may, however, be stated that some investigators have carried out research work on wood conductivity from ecological point of view. The work of various investigators is very briefly reviewed. Farmer (1918) observed a decreasing wood conductivity in trees from base to apex and correlated it with the decreasing cross-sectional area of water conducting vessels. He also found the deciduous plants to possess high specific conductivity as compared to evergreens. Holmes and Rivett (1918) working under the guidance of Prof. Farmer concluded that the main cause for variations in specific conductivity is the resistance offered by the wood, especially in view of the fact that similar observations are noted both in the temperate regions and the tropics. Inamdar and Shrivastava (1927) while working on the specific conductivity of a large number of plants concluded that the deciduous plants have a high specific conductivity as compared to evergreens like Mangifera.

Conductivity through Shoots

The grafted mango plants used for the investigation were of the 'Langra' variety. They were six months or one and a half years old after grafting. The young seedlings were raised from the mango stones and were grafted with 'Langra' tree in the Botanical Garden of the Punjab Agricultural College and Research Institute, Lyallpur. The stem region was divided into three portions: (1) The grafted portion, (2) The basal portion consisting of the stock, and (3) The portion of the scion above the graft. The length of all these pieces was kept uniform and each measured 10 cms. In order to obviate the entrance of air bubbles

into the stem pieces, they were cut under water. These stem pieces were further subjected to high vacuum to get rid of the air bubbles present in xylem vessels.

The apparatus used for determining the conductivity of the stem pieces was the one used by Farmer (1918) and Inamdar and Shrivastva (1927). The pieces of stem were attached to the apparatus and water was forced through at a pressure of 30 cms. of mercury column. The water which passed through the stem pieces in fifteen minutes was collected in graduated cylinders. At a time three or four readings were taken to ensure that the rate of flow through the stem pieces remained constant during observations. Conductivity of twelve grafted mangoes was investigated in 1941–42, when the grafted plants were six months old after grafting and it was repeated in 1942–43 to get confirmation of results obtained in the previous year.

The results obtained are given below:—

TABLE I

Quantity of water percolated through shoots

S. No	1941–42			S. No.	1942–43		
	Conductivity of the stem piece below the graft union (c.c.)	Conductivity of the graft union (c.c.)	Conductivity of the stem piece above the graft union (c.c.)		Conductivity of the stem piece below the graft union (c.c.)	Conductivity of the graft union (c.c.)	Conductivity of the stem piece above the graft union (c.c.)
1	2·5	0·04	2·0	1	3·0	0·04	2·0
2	2·7	0·04	2·2	2	2·7	0·04	1·9
3	2·9	0·04	1·9	3	3·3	0·04	1·0
4	3·7	0·04	1·3	4	2·8	0·04	1·5
5	3·0	0·04	2·9	5	2·0	0·08	2·9
6	3·3	0·04	2·7	6	3·1	0·04	2·5
7	3·7	0·04	1·6	7	4·8	0·30	2·0
8	3·9	0·40	1·5	8	3·5	0·04	1·5
9	5·2	0·30	1·3	9	4·1	0·04	1·0
10	3·9	0·04	1·5	10	5·0	0·50	1·9
11	3·1	0·04	1·6	11	4·4	0·04	1·8
12	3·0	0·76	1·7	12	3·6	0·60	1·2
Mean	3·4 ± ·2118	0·15 ± ·06264	1·85 ± ·1443	Mean	3·5 ± ·2552	·15 ± ·05578	1·76 ± ·1644

Data of Table I show that the greatest amount of water (3·4 C.C.) percolated through the basal portions of the stems in fifteen minutes and next best was the portion above the graft union. In the case of grafted portion a very small amount of water passed through amounting to 0·15 C.C. only. The difference in the amounts of water percolated through the grafted part and other parts was found to be statistically significant. The experiment was revised in 1942–43, and the results obtained were in consonance with the findings of 1941–42. The results conclusively confirm that high death rate in grafted plants is due to restricted flow of sap at the point of union of stock and scion. Stunted growth and bunchy shoots and leaves of some grafted mangoes have also been attributed to interrupted flow of sap.

Improved Technique of Grafting

With a view to accelerate the flow of sap through the grafted portion, some experiments were undertaken by giving cuts of varying depths to the stock and scion to improve the technique of grafting and afterwards compare their specific conductivity, when the union is made. The different degrees of depths tried were as follows:—

(1) Incised upto half the thickness of stock and scion.

(2) Incised upto one quarter thickness of stock and scion.

(3) Incised upto three-fourths thickness of stock and scion.

Twelve plants were operated as above under each treatment. When the plants were one and a half years old, their specific conductivity was determined. Observations were also made on the growth of these plants. The results obtained were tested on a large scale by grafting ninety mango seedlings under various treatments. The data obtained are given below in Table II (on p. 5).

Reference to Table II indicates that in fifteen minutes and under constant pressure, conductivity in lots of (1) half cuts, (2) one quarter cuts and (3) three-fourths cuts was 6·02, 3·14 and 1·84 C.C. respectively. This shows evidently that more water passed through the graft unions of the half cut plants as compared with other cuts in a unit time. In the year 1944–45, the experiment was repeated to verify the new method by grafting ninety mango seedlings under various treatments; the results corroborate those of 1942–43. The difference in the amounts of water percolated through the graft unions of half cut plants and other treatments was found to be statistically significant. It is also evident from the Table that death rate was very small in half cut grafted plants. In one quarter cuts and three-fourths cuts the mortality was very high. This indicates obviously that union was incomplete in one quarter cuts and three-fourths cuts as the flow of sap in these cases is much inhibited at the point of union resulting in almost blocking the supply of water to the shoot of the scion from the stock and caused stunted growth or withering.

TABLE II

Conductivity of graft unions operated under various treatments

	1942–43				1944–45		
Plant Nos.	Conductivity of graft union incised upto ½ the thickness (c. c.)	Conductivity of graft union incised upto ¼ the thickness (c. c.)	Conductivity of graft union incised upto ¾ the thickness (c. c.)	Plant Nos.	Conductivity of graft union incised upto ½ the thickness (c. c.)	Conductivity of graft union incised upto ¼ the thickness (c. c.)	Conductivity of graft union incised upto ¾ the thickness (c. c.)
1	8·0	5·5	1·5	1	5·9	2·3	1·5
2	8·1	3·4	4·0	2	5·6	4·7	2·0
3	9·0	0·9	1·8	3	6·4	2·2	1·6
4	5·1	2·3	1·0	4	3·8	3·4	1·8
5	5·4	2·0	2·0	5	8·0	3·9	2·1
6	4·7	2·5	1·5	6	5·1	2·0	1·2
7	4·0	1·0	*	7	4·7	4·5	2·2
8	3·5	*	*	8	7·8	4·4	1·6
9	3·9	*	*	9	9·1	2·0	2·5
10	4·4	*	*	10	6·7	1·9	1·1
11	5·7	*	*	11	6·4	2·8	2·3
12	*	*	*	12	5·3	3·9	2·1
				13	6·0	2·5	2·0
				14	5·9	3·0	*
				15	6·5	3·4	*
				16	5·3	2·7	*
				17	5·6	2·6	*
				18	6·0	3·2	*
				19	6·8	3·5	*
				20	5·9	4·0	*
				21	6·4	*	*
				22	5·7	*	*
				23	5·9	*	*
				24	4·8	*	*
				25	6·0	*	*
				26	5·3	*	*
				27	5·9	*	*
				28	6·1	*	*
				29	*	*	*
				30	*	*	*
Mean	5·61 ± ·5968	2·5 ± ·6752	1·96 ± ·3977	Mean	6·02 ± ·2062	3·14 ± ·1963	1·84 ± ·1209

N.B.—The mark " * " indicates dead plants.

GROWTH STUDIES

With a view to finding out the type of cut which denotes best growth, growth studies were continued. Data of newly formed branches and leaves on the scion were recorded in various incisions of grafts. The growth data obtained are tabulated below (Table III).

Table III indicates that the plants incised upto half the thickness produced approximately two new branches and twenty leaves. Grafted

TABLE III

Data of growth showing newly formed branches and leaves in various degrees of incisions of grafted mangoes

Plant Nos.	1942–43 Incised upto ½ the thickness — Number of newly formed Branches	Leaves	¼ thickness Branches	Leaves	¾ thickness Branches	Leaves
1	2	22	1	16	Nil	Nil
2	3	30	1	10	1	10
3	3	34	Nil	Nil	Nil	Nil
4	2	18	do	do	do	do
5	1	15	do	do	do	do
6	1	16	do	do	do	do
7	1	12	do	do	*	*
8	1	10	*	*	*	*
9	2	20	*	*	*	*
10	1	21	*	*	*	*
11	2	24	*	*	*	*
12	*	*	*	*	*	*

Plant Nos.	1944–45 Incised upto ½ the thickness — Number of newly formed Branches	Leaves	¼ thickness Branches	Leaves	¾ thickness Branches	Leaves
1	2	24	Nil	Nil	Nil	Nil
2	1	10	1	7	do	do
3	2	22	Nil	Nil	do	do
4	Nil	Nil	do	do	do	do
5	3	30	do	do	do	do
6	1	18	do	do	do	do
7	1	7	1	12	do	do
8	3	31	1	14	do	do
9	3	36	Nil	Nil	I	5
10	2	19	do	do	Nil	Nil
11	1	15	do	do	do	do
12	2	16	do	do	do	do
13	1	13	do	do	do	do
14	1	10	do	do	*	*
15	2	23	1	11	*	*
16	1	14	Nil	Nil	*	*
17	1	12	do	do	*	*
18	1	13	do	do	*	*
19	2	20	do	do	*	*
20	1	15	I	6	*	*
21	2	24	*	*	*	*
22	1	13	*	*	*	*
23	1	10	*	*	*	*
24	Nil	Nil	*	*	*	*
25	1	14	*	*	*	*
26	Nil	Nil	*	*	*	*
27	1	11	*	*	*	*
28	2	26	*	*	*	*
29	*	*	*	*	*	*
30	*	*	*	*	*	*

N.B.—The mark " * " indicates dead plants.

plants of one quarter cuts and three-fourths cuts, however, produced no new branches and leaves with the exception of three or four plants. From these observations it is quite obvious that the half cut shoots have better growth as compared with the other two treatments which have slow growing stunted shoots. The latter have also borne less number of leaves and they are all crowded into bunches. These results

correspond with the actual condition of the plants in mango nurseries. It is inferred conclusively that good growth in the half cut plants is due to a better flow of sap through the graft unions from the stock to the scion while in the other two treatments the flow of sap through graft union is slow, hence they show retarded growth.

Histology of Graft Unions

Histological studies of the shoots were also made along with the conductivity studies. Hand microtomic sections of graft unions of

Table IV

Data of wood formed at the sides of parenchymatous zone

1942–43

Plant Nos.	Incised upto					
	½ thickness		¼ thickness		¾ thickness	
	Length and width of parenchymatous zone (m.m.)	Width of secondary wood (m.m.)	Length and width of parenchymatous zone (m.m.)	Width of secondary wood (m.m.)	Length and width of parenchymatous zone (m.m.)	Width of secondary wood (m.m.)
1	1·22 × ·102	2·34	1·75 × ·306	1·99	2·81 × ·45	1·21
2	1·20 × ·103	2·41	1·81 × ·311	1·88	2·85 × ·512	1·84
3	1·29 × ·110	2·51	2·24 × ·278	1·21	2·74 × ·514	1·12
4	1·38 × ·130	2·24	2·86 × ·312	1·81	2·85 × ·623	1·40
5	1·30 × ·140	2·31	2·71 × ·314	1·62	2·45 × ·514	1·45
6	1·41 × ·165	2·25	2·24 × ·319	1·77	2·54 × ·491	1·21
7	1·78 × ·212	2·21	2·81 × ·351	1·32	*	*
8	1·71 × ·209	2·18	*	*	*	*
9	1·85 × ·212	2·18	*	*	*	*
10	1·32 × ·129	2·25	*	*	*	*
11	1·26 × ·013	2·31	*	*	*	*
12	*	*	*	*	*	*
	Mean	2·29 ± ·029		1·65 ± ·102		1·37 ± ·121

TABLE IV—(*Contd.*)

1944–45

Plant No.	Incised upto					
	½ thickness		¼ thickness		¾ thickness	
	Length and width of parenchymatous zone (m.m.)	Width of secondary wood (m.m.)	Length and width of parenchymatous zone (m.m.)	Width of secondary wood (m.m.)	Length and width of parenchymatous zone (m.m.)	Width of secondary wood (m.m.)
1	1·65 × ·122	2·45	2·34 × ·306	1·63	2·85 × ·511	1·24
2	1·63 × ·131	2·48	2·01 × ·211	2·00	2·84 × ·492	1·30
3	1·81 × ·141	2·51	2·41 × ·289	1·75	2·90 × ·613	1·12
4	1·98 × ·181	2·24	2·21 × ·234	1·85	2·90 × ·591	1·30
5	1·23 × ·111	2·71	2·74 × ·315	1·88	2·86 × ·512	1·25
6	1·71 × ·157	2·45	2·88 × ·319	1·74	2·97 × ·595	1·15
7	1·74 × ·161	2·40	2·77 × ·301	2·10	2·95 × ·476	1·40
8	1·45 × ·113	2·68	2·98 × ·291	2·00	2·91 × ·487	1·45
9	1·21 × ·109	2·78	2·78 × ·316	1·61	2·89 × ·512	1·23
10	1·64 × ·178	2·48	2·71 × ·325	1·70	2·71 × ·489	1·21
11	1·75 × ·157	2·45	2·77 × ·301	1·71	2·85 × ·451	1·41
12	1·85 × ·224	2·41	2·69 × ·209	1·81	2·79 × ·447	1·39
13	1·71 × ·212	2·42	2·50 × ·301	1·76	2·87 × ·514	1·31
14	1·79 × ·215	2·43	2·48 × ·209	1·75	*	*
15	1·58 × ·198	2–50	2·42 × ·302	1·82	*	*
16	1·62 × ·212	2·46	2·61 × ·311	1·72	*	*
17	1·71 × ·212	2·46	2·54 × ·313	1·73	*	*
18	1·76 × ·198	2·50	2·51 × ·321	1·84	*	*
19	1·54 × ·113	2·47	2·55 × ·329	1·83	*	*
20	1·68 × ·198	2·38	2·58 × ·324	1·90	*	*
21	1·74 × ·121	2·46	*	*	*	*
22	1·64 × ·131	2·41	*	*	*	*
23	1·71 × ·151	2·40	*	*	*	*
24	1·86 × ·223	2·31	*	*	*	*
25	1·88 × ·212	2·44	*	*	*	*
26	1·75 × ·195	2·47	*	*	*	*
27	1·81 × ·221	2·51	*	*	*	*
28	1·83 × ·225	2·49	*	*	*	*
29	*	*	*	*	*	*
30	*	*	*	*	*	*
	Mean	2·47 ± ·014		1·80 ± ·028		1·29 ± ·018

* *N.B.*—The mark " * " indicates dead plants.

(1) six months and (2) one and a half years old after grafting, were cut. Parenchymatous tissue was found in between the wood of the stock and the scion and distortion of xylem at the point of union as well as formation of wound gum in xylem vessels. Chocking of xylem vessels with wound gum and formation of parenchymatous tissue are responsible for inhibiting the flow of the sap from the stock to the scion at the point of union. It was observed that the wood elements formed at the sides of parenchymatous tissue are responsible for conduction of the sap from the stock to the scion (Fig. 1). In the half cut plant

there is comparatively very little parenchymatous zone and formation of wood at the ends of zone takes place very rapidly in comparison to one quarter cuts and three-fourths cuts. In the latter there is a large mass of parenchymatous zone in between the wood of the stock and the scion and at the sides. Sections of every graft union of one and a half years in age were cut in 1942–43 and 1944–45. In every section, length and width of parenchymatous zone formed in between the wood of the stock and the scion and width of secondary xylem from the end of parenchymatous zone were measured (Table IV).

Table IV shows that the length and width of parenchymatous zone formed in grafting was less in half cut plants in comparison to one quarter cuts and three fourths cuts. The width of secondary wood in half cuts, one quarter cuts and three fourths cuts were 2·47 mm., 1·80 mm. and 1·29 mm. respectively. This indicates that cambium activity was maximum in the half cut plants in comparison to the other two treatments. The difference in the secondary wood of half cut plants and other treatments was found to be statistically significant. The results of 1944–45 confirm the results of 1942–43.

Summary

The young seedlings raised from the mango stones were grafted with 'Langra' tree in the Botanical Garden of the Punjab Agricultural College and Research Institute, Lyallpur. The grafted mango plants used for investigation of conductivity were (1) six months, and (2) one and a half years in age, after grafting. The data of conductivity experiments of grafted mango plants six months in age have revealed that the greatest amount of water (3·4 c.c.) percolated through the basal portions of the stems in fifteen minutes and at 30 cms. of mercury pressure and next best was the portion above the graft union, while very small amount of water passed through the graft union amounting to 0·15 c.c. only. The results conclusively confirm that high death rate, stunted growth and bunchy leafy shoots of grafted mangoes are caused by interrupted flow of sap at the point of the union of stock and scion.

With a view to promote the flow of sap through the graft union and thus reduce death rate various depths of cuts to the stock and scion were tried:—

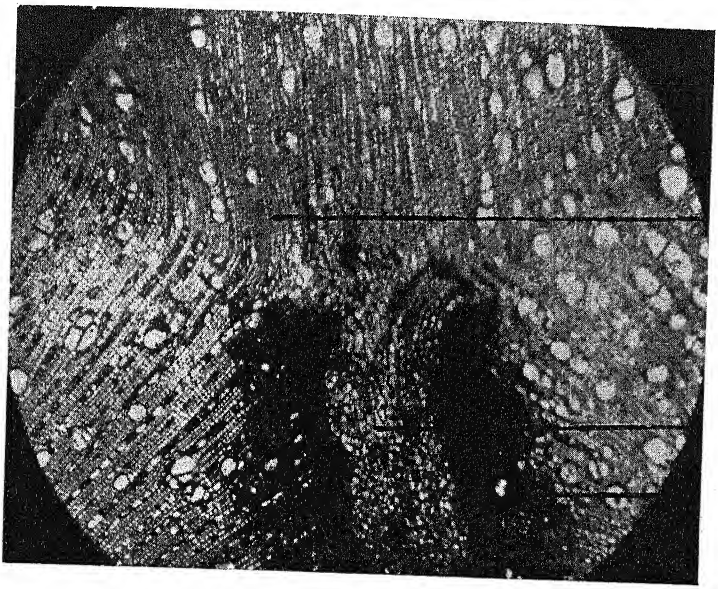
(1) Incised upto half the thickness of stock and scion.

(2) Incised upto one quarter thickness of stock and scion.

(3) Incised upto three-fourths thickness of stock and scion.

The results show that conductivity of the half cuts, one quarter cuts and three-fourths cuts at the age of one and a half years was 6·02, 3·14 and 1·84 c.c. respectively. This shows that more water passed through half cuts as compared with other cuts in a unit time. Growth studies have also established that half cut plants exhibit good growth in comparison to the other two treatments.

Histological studies have shown the formation of parenchymatous tissue in between the wood of the stock and the scion. Chocking of xylem vessels with wound gum and formation of parenchymatous tissue



JAI CHAND LUTHRA AND MADAN MOHAN LAL SHARMA—

SOME STUDIES ON THE CONDUCTIVITY AND HISTOLOGY OF GRAFTED MANGO SHOOTS

are responsible for inhibiting the lateral flow of sap from the stock to the scion. Flow of sap from the stock to the scion takes place at the union through the wood formed at the ends of parenchymatous zone. Width of secondary wood in graft unions of one and a half years in age from the end of parenchymatous zone was 2·47, 1·8 and 1·29 mm. in half cuts, one quarter cuts and three fourths cuts respectively. This shows that cambium activity was greater in half cuts in comparison to other treatments. The main reason for high mortality in one quarter cuts and three fourths cuts is the formation of a thick mass of parenchymatous tissue. The new technique evolved is that for inarching the linear cuts on the scion and the stock should be half the width through the shoots to bring about proper union and maintain a free passage of the sap.

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EXPLANATION OF THE PLATE

Mangifera indica.—Transection of the stem in the region of the graft showing the formation of wood at the sides of the parenchymatous tissue. × 465.

5*

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CONTENTS

RULES OF THE INDIAN BOTANICAL SOCIETY

(*With amendments up to 3-1-1944*)

Founded December 6, 1920

(*Registered under Act XXI of 1860*)

The Indian Botanical Society had its inception in a resolution passed by the Botany Section of the Indian Science Congress at the Nagpur meeting in January 1920. A Committee of Organisation was consequently formed to carry this resolution into effect. This committee consisted of the late Dr. P. Brühl of the University College of Science, Calcutta, the late Rao Bahadur K. Rangachariar of the Agricultural College, Coimbatore, the late Rai Bahadur Prof. Shiv Ram Kashyap of the Government College, Lahore, Prof. Birbal Sahni, then of the Benares Hindu University, Benares, Dr. W. Burns, then of the College of Agriculture, Poona, and the late Dr. Winfield Dudgeon of the Ewing Christian College, Allahabad, with Dr. Dudgeon as Chairman.

In October 1920 the Committe sent out a letter to as many botanists as could be located in India, inviting them to become charter Members of the new Society. It was agreed that 25 members would be considered sufficient for founding the Society and that office-bearers should be elected when this number was reached. The response to this invitation was so immediate and hearty that it was possible to hold elections for office-bearers of the Society by about the middle of November. Upon completion of the election on December 6th the Society was declared duly organised, and the Committee of Organisation ceased to exist.

NAME, PURPOSE AND ACTIVITIES

1. The Society shall be called the Indian Botanical Society.

2. The purpose of the Society shall be to promote the cause of Botany in India in all its aspects.

3. The Society shall attempt to achieve this purpose

(*a*) By publishing a Botanical Journal.

(*b*) By holding general and local meetings with a view to diffusing botanical knowledge among the public and facilitating intercourse between members.

(*c*) By encouraging original investigations.

(*d*) By organising efforts to create facilities for botanical work in the country.

(*e*) By starting branches in various centres, if ten or more members apply from each centre.

(*f*) By appointing sub-committees wherever and whenever they may be required.

4. Membership shall be open to all persons interested in Botany.

5. There shall be two classes of members, Ordinary and Honorary.

6. Members shall be admitted to the Society after being nominated by any two Ordinary Members and elected either by a unanimous vote of the Executive Council of the Society or by a simple majority of the members present at an annual meeting.

7. All members of a standing of 5 years or more shall be designated Fellows of the Society.

8. Ordinary Members shall be entitled to all the privileges of the Society, and shall receive *gratis* all the publications of the Society.

9. Ordinary Members may become Life Members upon payment of Rs. 150 either in a lump sum, or in instalments within a year from the time of their application for life membership, provided that any ordinary Member who has already paid a number of annual subscriptions may be allowed a rebate at the rate of half the annual subscriptions paid, up to a maximum of eight years.

10. The number of Honorary Members shall not, at any time, exceed ten. Such membership shall be restricted to persons eminent for their contributions to Botanical Science. Honorary Members shall be elected after the unanimous recommendation of the Executive Council, and by four-fifths majority of those present and voting at the Annual Meeting. They shall enjoy all the privileges of Ordinary Members, without payment of fees, excepting that of holding office.

PRIVILEGES

11. All Ordinary and Honorary Members shall receive a copy of the Journal free.

12. The local branches shall receive a copy of the Journal free. They shall also have the right to admit local student-members on payment of Membership Fee of Re. 1 per annum. This money shall be utilised by the Local Branches for meeting their expenses.

13. Ordinary and Honorary Members shall have the right of communicating papers for the meetings and the Journal, and all members, including student-members, shall have the right of attending the Annual Meetings, but the student-members shall have no votes.

14. Fellows of the Society shall be entitled to use the abbreviations F. B. S. after their names.

WITHDRAWAL OF MEMBERS

15. A Member may withdraw from the Society by signifying his wish to do so in a letter addressed to the Secretary. The Society, however, shall not be liable to return any fee that may have been paid by the member in advance.

16. A withdrawing member whose subscription is not in arrear shall automatically recover the privileges of membership without re-election if he rejoins the Society within six months of withdrawal. He shall then be liable to pay all dues as if he had not withdrawn at all.

Subscriptions

17. The annual subscription of Ordinary Members shall be Rs. 12-8.

18. The financial year shall begin on the 1st of October and end on 30th September, and the annual subscriptions shall be paid in advance to the Treasurer, provided that new members elected after the first of August shall be exempted from payment of dues for the closing financial year.

19. Members whose subscriptions have expired and who have not paid for the current year will receive the first number of the current volume of the Journal by V. P. P.

Subscriptions in Arrears

20. Members whose subscriptions are in arrears shall be excluded from the privileges of membership until they shall have paid the arrears. A list of all such members, showing the amounts due from them shall be submitted by the Secretary to the President at each annual meeting, and it shall be read out at the request of any member present at the meeting.

21. The Treasurer shall, at the end of the financial year, send a letter or bill with a request to renew his or her subscription to every member at his or her last known address. If the subscription remains unpaid and the V. P. P. (Rule 19) is refused, the Council may remove the member's name from the Society's register.

22. Any member whose name has been removed under the preceding rule may be re-elected on payment of his arrears.

The Management

23. There shall be:—

(*a*) An Executive Council, which shall carry on all the affairs of the Society except those concerning the publication and distribution of the Journal.

(*b*) The Editorial Board, which shall be responsible for the publication and distribution of the Journal.

The Executive Council

24. The Executive Council shall consist of:—

(*a*) the President, (*b*) Two Vice-Presidents (one of whom shall be the retiring President of the Society), (*c*) the Secretary, (*d*) the Treasurer, (*e*) the Editor-in-Chief and (*f*) ten elected Councillors.

25. The President, Vice-Presidents and Councillors shall

three years. Each year the Councillors who have been in office for three consecutive years shall retire from the Council and shall not be eligible for re-election until after the lapse of one year from the date of their retirement. The time of retirement of office bearers shall be immediately after the close of the Annual Meeting.

26. The President (or, in his absence one of the Vice-Presidents) shall preside, if present, at all general meetings of the Society and shall deliver an address at the Annual Meeting at which he presides.

27. The Secretary shall perform the duties usually devolving upon that office.

28. The Treasurer shall be responsible for the financial affairs of the Society during the term of his office and shall submit by the end of October each year the accounts of the Society for the current financial year to a certified Auditor appointed by the President.

29. The time, place, and agenda of the Annual General Meeting shall be arranged by the Executive Council, as far as possible in co-operation with other organisations having a similar purpose.

THE EDITORIAL BOARD

30. The Editorial Board shall consist of:—

(*a*) Four Members elected for four-year periods and retiring in rotation.

(*b*) The Treasurer (*ex-officio*), who shall also be the Business Manager of the Journal.

(*c*) The Secretary of the Society (*ex-officio*.)

(*d*) One member nominated annually by each University which contributes Rs. 150 or more to the Society annually.

31. The Editor-in-Chief shall be elected by the Editorial Board from among its own members.

32. The subscription to the Journal from non-members shall be Rs. 15 or its equivalent in foreign currency.

ELECTIONS TO OFFICES

33. All elections to the office shall take place at the annual Meeting of the Society, *interim* vacancies being filled up by the Executive Council.

34. The following procedure shall be adopted for all elections to office:—The Secretary shall cause a list of members of the Society to be circulated before the 31st August in each year and invite from members entitled to vote nominations for each office falling vacant to be received before the 30th September.

The Executive Council shall also nominate one member for each office falling vacant. For this the Secretary shall cause a list of the members of the Society to be circulated before the 31st August each year and invite Executive Councillors to propose names for each office falling vacant to be received before the 15th September. The names so proposed by the Executive Councillors shall be circulated to them for voting, and those obtaining the largest number of votes, shall be considered as nominees of the Executive Council. The voting papers from the Executive Councillors shall be received before the 7th October. A list of names proposed by the members together with the nominations of the Council shall be circulated to members before the 30th November each year.

35. All voting shall be by secret ballot on forms supplied by the Secretary and returned, as advised by him, in special envelopes provided for the purpose.

36. Votes shall be scrutinized at the Annual Meeting.

37. A majority shall elect. Tie ballots shall be decided by lot.

38. All retiring office-bearers shall be eligible for re-election, except those mentioned in Rules 20 and 23.

Amendment to the Rules

39. The above rules may be amended at any Annual General Meeting by a three-fourths majority of the members present and voting. Amendments may be proposed by any member and must reach the Secretary in time for circulation to all members of the Society at least one month before the meeting.

LIST OF THE PAST OFFICERS OF THE SOCIETY

PRESIDENTS

1921	Prof. Winfield Dudgeon.
1922	Rao Bahadur K. Rangachariar.
1923	Prof. B. Sahni.
1924	Prof. S. R. Kashyap.
1925	Prof. R. S. Inamdar.
1926	Prof S. L. Ajrekar.
1927	Rev. Dr. E. Blatter.
1928-29	Prof. M. O. P. Iyengar.
1930	Prof. P. Parija.
1931-32	Prof. T. Ekambaram.
1933	Prof. S. P. Agharkar.
1934	Prof. R. H. Dastur.
1935	Prof. J. H. Mitter.
1936-37	Prof. S R. Bose.
1938	Prof. H. G. Champion.
1932	Prof. Rai Bahadur K. C. Mehta.
1940	Prof. H. Chaudhuri.
1941	Prof. S. L. Ghose.
1942	Prof. M. A. Sampathkumaran.
1943	Dr. K. Bagchee.
1944	Prof. Y. Bharadwaja
1945	Dr. N. L. Bor.

VICE-PRESIDENTS

1921	Dr. W. Burns.
1922	Prof. S. P. Agharkar.
1923	Prof. M. O. P. Iyengar.
1924	Prof. M. A. Sampathkumaran.
1925	Prof. S. L. Ajrekar.
1926	Prof. P. Parija.
1927	Dr. H. Chaudhuri.
1928-29	Prof. S. L. Ajrekar.
1930	Dr. S. K. Mukerji.
	Dr. T. Ekambaram
1931-32	Dr. S. L. Ghose.
	Prof. P. Parija.
1933	Prof. T. Ekambaram.
	Prof. J. H. Mitter.
1934	Prof. M. O. P. Iyengar.
	Prof. J. H. Mitter.
1935	Prof. P. Parija.
	Prof. S. R. Bose.
1936	Prof. P. Parija.
	Dr. K. Bagchee.
1937	Prof. B. Sahni.
	Prof. H. G. Champion.
1938	Prof. S. L. Ghose.
	Prof. R. H. Dastur.

1939	Mr. H. G. Champion.
	Dr. H. Chaudhuri.
1940	Prof. K. C. Mehta.
	Dr. K. Bagchee.
1941	Dr. H. Chaudhuri.
	Prof. Shri Ranjan.
1942	Prof. Y. Bharadwaja.
	Dr. N. L. Bor.
1943	Prof. P. Parija.
	Prof. M. A. Sampathkumaran.
1944	Dr. A. C. Joshi.
	Dr. P. Maheshwari.
1945	Prof. H. Chaudhuri.
	Dr. B. P. Pal.

SECRETARIES AND TREASURERS

1921-22	Prof. S. R. Kashyap.
1923	Prof. R. S. Inamdar.
	Prof. B. Sahni.
1923	Mr. N. K. Tiwary.

SECRETARIES

1929-30	Mr. N. K. Tiwary.
1931	Prof. Winfield Dudgeon.
1932-34	Dr. S. K. Mukerji.
1934-38	Dr. E. K. Janaki Ammal.
1933-41	Prof. Y. Bharadwaja.
1942-44	Prof. G. P. Majumdar.
1945	Dr. S. N. Das Gupta.

TREASURERS

1929-30	Prof. M. O. P. Iyengar.
1930-33	Prof. T. Ekambaram.
1933-34	Prof. M. O. P. Iyengar.
1944	Prof. G. P. Majumdar.
1945	Prof. A. C. Joshi.

CHIFF EDITORS

1921-26	Prof. P. F. Fyson.
1927-28	Prof. B. Sahni.
1929-30	Prof. M. O. P. Iyengar.
1930-34	Prof. S. R. Kashyap.
1934-42	Prof. P. Parija.
1943-44	Prof. M. O. P. Iyengar.
1945	Prof. M. O. P. Iyengar.

BUSINESS MANAGERS

1925-30	Prof. M. O. P. Iyengar.
1930-33	Prof. T. Ekambaram.
1933-43	Prof. M. O. P. Iyengar.
1944-45	Prof. A. C. Joshi.

OFFICERS OF THE SOCIETY 1946

PRESIDENT.

Prof. Shri Ranjan, M. Sc. (Cantab.), Docteur-es-Sciences, F. A. Sc.,

VICE-PRESIDENTS.

Dr. N.L. Bor, M.A., D.Sc., F.L.S., I.F.S., F.N.I., C.I.E.

M.S. Randhawa, Esq., M.Sc., I.C.S., F.N.I.

EDITOR-IN-CHIEF.

Prof. M.O.P. Iyengar, M.A., Ph. D., F.L.S., F.N.I.

TREASURER AND BUSINESS MANAGER.

Prof. A.C. Joshi, D.Sc., F.N.I.

SECRETARY.

Dr. S.N. Das Gupta, M.Sc., Ph.D., D.I.C.

ELECTED MEMBERS OF THE EXECUTIVE COUNCIL.

Prof. P.L. Anand, M.Sc., Ph.D.
Prof. J.F.R.d' Almeida, B.A., M.Sc.
Prof. S.P. Agharkar, M.A., Ph.D.,F.L.S., F.N.I.
Dr. B.P.Pal, M.Sc., Ph.D., F.L.S.
Prof. M.O.P. Iyengar, M.A.,Ph.D.,F.L.S.,F.N.I.
Prof. T.S. Mahabale, B.A.,M.Sc., Ph.D.
Prof. G.P. Majumdar, M.Sc., Ph.D., F.N.I.
Prof. R.L. Nirula, B.Sc., Ph.D., D.I.C.
Dr. P.Parija, M.A., D.Sc., F.N.I., I.E.S., O.B.E.
Prof. L.N. Rao,, M.Sc., Ph.D.

EDITORIAL BOARD.

Prof. M.O.P. Iyengar, M.A., Ph.D., F.L.S., F.N.I.
Dr. B.P.Pal, M.Sc., Ph.D., F.L.S.
Prof. S.P. Agharkar, M.A., Ph.D., F.L.S., F.N.I.
Prof. G.P. Majumdar, M.Sc., Ph.D., F.N.I.
Dr. P. Maheshwari, D.Sc., F.N.I.
Prof. A.C. Joshi, D.Sc., F.N.I. (Ex-Officio).
Dr. S.N. Das Gupta, M.Sc., Ph.D., D.I.C. (Ex.Officio).

MINUTES OF THE TWENTY-FIFTH ANNUAL GENERAL MEETING

(Held at Bangalore on January 4, 1946.)

The Twenty-fifth Annual General Meeting of the Indian Botanical Society was held on January 4, 1946 at Bangalore, in the room of the Botany Department, with Dr. B. P. Pal, Vice-President of the Society, in the chair.

The following business was transacted :

1. The following resolutions were moved from the Chair and unanimously passed, all present standing.

"That the Society records its deep sense of loss at the sad demise of Prof. J. H. Priestley, Professor of Botany, University of Leeds (England) who was an Honorary Member of the Society since 1944, and that a copy of the resolution be forwarded to the members of the bereaved family" (died in 1944).

"That the Society records its deep sense of loss at the sad demise of Prof. A. H. R. Buller, Emeritus Professor of Botany, University of Manitoba, (Canada) who was an Honorary Member of the Society since 1939, and that a copy of the resolution be forwarded to the members of the bereaved family" (died on 4th July 1944.)

"That the Society records its deep sense of loss at the sad demise of Dr. Maurice Jacques LeGoc (Colombo) who was a member of our Society since 1939, and that a copy of the resolution be forwarded to the members of the bereaved family" (died on 16th March 1945.)

"That the Society records its deep sense of loss at the sad demise of Prof. S. L. Ghose, Professor of Botany, Government College, Lahore, who was the President of the Society (1941) and Vice-President (1931-32 and 1938), and that a copy of the resolution be forwarded to the members of the bereaved family" (died on 24th March 1945.)

"That the Society records its deep sense of loss at the sad demise of Prof. H. Chaudhuri, Professor and Head of the Department of University Teaching in Botany and Director, Kashyap Research Laboratory, Panjab University, Lahore, who was the President (1940), Vice-President (1927, 1939, 1941 and 1945) and the member of the Editorial Board of the Indian Botanical Society since 1939, and that a copy of resolution be forwarded to the members of the bereaved family" (died on 9th August 1945.)

2. The minutes of the last Annual General Meeting held at Nagpur were read and confirmed.

3. The Secretary read the Annual Report for the year 1945 which was unanimously passed.

4. The Secretary read the statement of audited accounts for the year ended 30th September 1945 and the same was passed unanimously.

5. The Secretary reported the unanimous election of the following Life-members, Honorary members and Ordinary members of the Society since the last Annual meeting.

Hony.-Members : Prof. V. H. Blackman (England)
Prof. T. G. Halle (Sweden)

Life-Members : Dr. N. L. Bor (Shillong)
Dr. Donald A. Johansen (California, U. S. A.)

Ordinary Members :

1.	Dr. T. S. Sadasivan	(Madras.)
2.	Mr. R. Subrahmanyan	,,
3.	Mr. K. S. Venkataramani	,,
4.	Mr. T. V. Desikachary	,,
5.	Mr. C. V. Subramanian	,,
6.	Mr. S. Doraiswami	,,
7.	Mr. A. B. Joshi	(New Delhi)
8.	Dr. S. Ramanujam	,,
9.	Dr. J. J. Chinoy	,,
10.	Mr. R. B. Deshpande	,,
11.	Mr. K V. Vishwanath	,,
12.	Mr. Abdul Hameed Sheikh	,,
13.	Mr. H. L. Chakraverti	,,
14.	Mr. N. P. Chowdhury	,,
15.	Mr. D Srinivasachar	,,
16.	Mr. Harbhajan Singh	,,
17.	Prof. S. R. Sen Gupta	(Calcutta)
1 .	Mr. Basheer Ahmad Razi	,,
19.	Dr. G. S. Puri	(Lucknow)
20.	Dr. R. V. Sitholey	,,
21.	Dr. R. S. Bhatt	,,
22.	Mr. G. S. Verma	,,
23.	Prof. J. Hsü	,,
24.	Mr. S. C. Agarwala	,,
25.	Mr. B. S Trivedi	,,
26.	Prof. Som Prakash	(Agra)
27.	Dr. S Sinha	,,
28.	Mr. Dayal Singh Johar	,,
29.	Prof. S. K. Bhattacharjee	(Pondicherry)
30.	Dr. Donald A. Johansen	(California, U. S. A.)
31.	Dr. Pushkar Nath	(Simla)
32.	Mr. S. D. Chowdhury	(Shillong)
33.	Mr. J. G. Srivastava	(Shikarpur, Sind.)

7. The following new members were elected unanimously after their names had been duly proposed and seconded :

1.	Mr. D. D. Awasthi	(Lucknow)
2.	Miss A. H. Mackenzie	,,
3.	Mr. J. N. Rai	,,
4.	Mr. S. D. Saksena	,,
5.	Mr. R. N. Lakhanpal	,,
6.	Mr. A. T. Kovoor	(Madras)
7.	Mr. K. V. Ramakrishnan	,,
8.	Miss T. S. Sarojini	,,
9.	Miss C. Thankam	,,
10.	Miss L. Yogeswari	,,
11.	Mr. D. D. Pant	(Allahabad)
12.	Dr. K. D. Thampan	(Calicut)
13.	Dr. P. N. Mehra	(Lahore)
14.	Dr. M. F. Chandraratna	(Peradeniya)

8. The Chairman appointed Profs. Sayeed-ud-din and L. N. Rao as scrutineers of ballot papers for the election of office bearers for the year 1946. On their report the following result was announced :

President :—Prof. Shri Ranjan (Allahabad)

Vice-Presidents:—Dr. N. L. Bor (Shillong)
Mr. M. S. Randhawa (New Delhi)

Editorial Board :—Dr. B. P. Pal (New Delhi)
Prof. S. P. Agharker (Calcutta.)

Councillors :—Dr. P. Parija (Cuttack)
Dr. B. P. Fal (New Delhi)
Prof. M. O. P. Iyengar (Madras)
Prof. G. P. Majumdar (Calcutta)
Prof. R. L. Nirula (Nagpur)
Prof. S. P. Agharkar (Calcutta)
Prof. T. S. Mahabale (Ahmedabad)
Prof. P. L. Anand (Lahore)
Prof. L. N. Rao (Bangalore)
Prof. J. F. R. d'Almeida (Bombay.)

9. The resolutions moved by Prof. G. P. Majumdar, and amended by the Executive Council were considered and passed unanimously.

Resolutions.

(i) That the Fellowships be instituted in the Society from the year 1946.

(ii) That all members of a standing of 5 years or more be designated Fellows of the Society from 1946.

(iii) That the Fellows of the Society be entitled to use the abbreviations F. B. S., after their names.

9. The amendment to the rule 19 as proposed by Prof. G. P. Majumdar was passed unanimously which now reads as follows:

Rule 19.

The Treasurer shall, at the end of the finanical year, send a letter or bill with a request to renew his or her subscription to every member at his or her last known address. If the subscription remains unpaid and the V. P. P. (Rule 17) is refused, the Council may remove the member's name from the Society's register.

10. The amendment to the rules 21 (a) & (b) as proposed by Prof. G. P. Majumdar was passed unanimously which now reads as follows:

Rule 21 (a).

An Executive Council which shall carry on all the affairs of the Society except those concerning the publication and distribution of the Journal.

Rule 21 (b).

The Editorial Board, which shall be responsible for the publication and distribution of the Journal.

11. The amendment to the rule 23 as proposed by Prof. G. P. Majumdar was passed which now reads as follows:

Rule 23.

The President, Vice-Presidents and Councillors shall serve for one year each, the Secretary and the Treasurer for three years. Each year the Councillors who have been in office for three consecutive years shall retire from the Council and shall not be eligible for re-election until after the lapse of one year from the date of their retirement.......................... ....

12. The recommendation of the Executive Council regarding Foreign Secretaries was considered and provision was made for one Honorary Foreign Secretary for each of the foreign countries.

Dr. P Maheshwari was appointed Foreign Secretary for America for one year for 1946.

13. The following Budget Estimates for 1945-46 as presented by the Secretary in the absence of the Treasurer was adopted.

14. The recommendation of the Executive Council regarding the provision of Rs. 1,200 in the budget estimates for accommodating the back volumes and the Library of the Society that the matter should be settled by correspondence among Prof. M O. P. Iyengar, Prof. A. C. Joshi and Dr. S. N. Das Gupta was adopted.

BUDGET ESTIMATE.

Receipts

	Rs.	a.	p.
To opening balance ...	5,648	13	4
To subscriptions from ordinary members ...	1,500	0	0
To subscriptions to the Journal :			
Indian ...	900	0	0
Foreign ...	400	0	0
To grants-in-aid .			
From Universities ...	250	0	0
From Rockefeller Foundation ...	1,000	0	0
To sale of back volumes ...	100	0	0
To sale of reprints ...	200	0	0
To deficit over income ...	2,254	10	8
Total ...	12,253	8	0

Payments

	Rs.	a.	p.
By establishment charges of the offices of the Secretary, Treasurer & Business Manager and Editor-in-Chief ...	720	0	0
By House rent ...	144	0	0
By postage ...	225	0	0
By audit fee (1945-46) ...	40	0	0
By bank commission ...	15	0	0
By printing charges and stationery for various offices ...	200	0	0
By printing charges for the year book ...	250	0	0
By printing charges for the Journal Vol. 23, Nos. 3 & 4 index and Vol. 24, Nos. 1 & 2 published during 1944-45 ...	3,000	0	0
By printing charges for the Journal 4 Nos. to be published during the year 1945-46 ...	3,500	0	0
By cost of almirahs for accommodating the back volumes and the Library of the Society ...	1,200	0	0
By railway freight ...	800	0	0
By refund of the advance from the Reserve Fund obtained during 1943-44	1,234	8	0
By credit to the Reserve Fund :			
Life-membership fee for 1943-44 ...	481	4	0
Life-membership fee for 1944-45 ...	443	12	0
Total ...	12,253	8	0

15. With a vote of thanks to the retiring office-bearers the meeting was dissolved.

Chariman.
25th Annual Meeting.

Secretary.
Indian Botanical Society.

ANNUAL REPORT FOR THE YEAR 1944-45 OF THE INDIAN BOTANICAL SOCIETY

The Executive Council of the Indian Botanical Society have pleasure in submitting the following Annual Report of the Society for the year ending 30th September 1945.

Meetings:

The twenty fourth Annual Meeting of the Society was held at Nagpur on the 3rd January 1945 in the room of the Botany Section of the Indian Science Congress with Dr. P. Maheshwari, the Vice-President in the Chair in the absence of the President who had resigned.

The Society recorded its deep sense of sorrow at the sad demise of Prof. M. A. Sampathkumaran who had been intimately connected with the Society since its inception in 1920.

The normal business of the Society was then transacted.

The Office-bearers for the year 1945 were elected at the meeting. The Executive Council and the Editorial Board, including representative from the Madras University, were constituted as follows:

President:	...	Dr. N. L. Bor (Shillong)
Vice-Presidents:	...	Dr. B. P. Pal (New Delhi) Dr. H. Chaudhuri (Lahore)
Secretary:	...	Dr. S. N. Das Gupta (Lucknow)
Treasurer and Business Manager:	...	Dr. A. C. Joshi (New Delhi now Lahore)
Councillors:	...	Prof. P. L. Anand (Lahore) Prof. F. R. Bharucha (Bombay) Prof. M. O. P. Iyengar (Madras) Prof. T. S. Mahabale (Ahemadabad) Prof. G. P. Majumdar (Calcutta) Prof. R. L Nirula (Nagpur) Prof. T. S. Raghavan (Annamalainagar) Prof. L. N. Rao (Bangalore) Prof. P. Parija (Cuttack). Prof. M. Sayeed-ud-Din (Hyderabad Deccan)
Editorial Board:	...	Prof. M. O. P. Iyengar (Editor-in-Chief) Prof. H. Chaudhuri Prof. S. P. Agharkar Dr. P. Maheshwari Prof. G. P. Majumdar Dr. A. C. Joshi (Ex-officio) Dr. S. N. Das Gupta (Ex-officio)

The Executive Council held one meeting during the year under report on the 3rd January 1945 in the room of the Botany Section of the Indian Science Congress, Nagpur.

Deaths:

During the year under report the Society has lost three members, Dr. Maurice J. LeGoc (Colombo), Prof. S. L. Ghose (Lahore) and Prof. H. Chaudhuri (Lahore).

The Society has lost two Honorary Members in 1944: Prof. J. H. Priestley (Yorkshire, England) and Prof. A. H. R. Buller (Winnipeg, Canada).

At the end of the financial year the number of members of the Society was as follows:

Ordinary members	...	153
Life members	...	30
Honorary members	...	6

During the year 46 ordinary members have been admitted to the Society. Of these 32 members have been admitted since the last Annual General meeting.

The number of life members has increased by 2. Dr. N. L. Bor has his membership converted and Dr. Donald A. Johansen (California) is a newly admitted member.

Two members have resigned during the year. Unfortunately the number of defaulters whose names still exist in the membership list is considerable (40). Ten members are defaulters for 2 years or more and 30 members for one year. It is hoped that many of these will pay up their dues and continue their membership.

Subscribers (other than members) of the Journal:

The Journal was subscribed by 86 institutions of which 60 were from India and 26 from abroad.

Publications:

During the year under report were published nos. 3, 4 and index of volume XXIII and nos. 1, 2 of volume XXIV.

Exchanges:

We had exchange relations with 25 institutions.

Library:

The publications received were duly added to the Library (Appendix A).

Donations:

Two Universities and the Rockefeller Foundation, New York, U. S. A., have kindly continued their annual contribution.

		Rs.	A.	P.
Madras University	...	150	0	0
Travancore	...	100	0	0
Rockefeller Foundation (Through the National Institute of Sciences, India)	...	750	0	0

Accounts.

The accounts of the Society for the year ending 30th September 1945, were audited by Messrs Walter Chaudick and Co., Ltd. The receipts and payments accounts, as for the year ending the 30th September 1945, submitted by the auditors are given in Appendix B.

		Rs.	A.	P.
The Total actual receipt during the year	...	4499	12	4
The total payment ,, ,, ,,	...	2059	15	8
Surplus	...	2439	12	8
Add (the balance of the previous year)	...	3209	0	8
The total closing balance	...	5648	13	4

Against this closing balance of Rs. 5648-13-4 there are the following liabilities:

Liabilities:

On printing (1944-45)	...	3,000	0	0
Advance to Reserve Fund obtained during 1943-44		1234	8	0
To credit to Reserve Fund				
Life membership (1943-44)	...	481	4	0
Life membership (1944-45)	...	443	12	0
Total	...	5159	8	0

At the beginning of the year 1st October 1944 the cash position of the Society was as follows:

Post office cash certificates at cost	...	5730	0	0
Cash with Imperial Bank of India	...	2955	14	3
Cash with Secretary	...	1	15	0
Cash with the Chief Editor	...	101	4	2
Cash with the Business Manager	...	149	15	3
Total	...	8939	0	8

At the end of the year 30th September 1945 the cash position was as follows:

Post office cash certificates	...	5730	0	0
Cash with the Imperial Bank of India	...	5154	4	7
Cash with the Treasurer	...	408	1	3
Cash with the Secretary	...	52	8	3
Cash with the Editor-in-Chief	...	33	15	3
Total	...	11,378	13	4

In connection with the resolutions passed in the last Annual General Meeting (1945) to make the Journal bi-monthly, it was decided to take up the matter immediately after the regular publication of the Journal has been ensured.

We regret that due to unavoidable circumstances it has not been possible to arrange for the Presidential Address of the Society this year. The Celebration of the Silver Jubilee of the Society has been postponed for 1947.

APPENDIX A

NEW ADDITIONS TO EXCHANGE PUBLICATIONS RECEIVED BY THE INDIAN BOTANICAL SOCIETY

(Since the publication of the Lists in 1938, 1939, 1940, 1941, 1942, 1943, 1944 and 1945)

Serial numbers as in the Lists published in previous years.

10. Annals of the Missouri Botanical Garden.
    Vol. XXX, 1, 3. September 1944.
    ,, 4. Novemeber 1944.
    ,, XXXI, 1. February 1945.

33. Contributions from the Boyce Thompson Institute for plant Research.
    Vol. 12, Nos. 4, 5, 6, 7.
    13, Nos. 1 to 10.
    Professional Paper, Vol. 1, Nos. 33, 34, 35 & Index to Vol.1.
    ,, ,, Vol. 2, Nos. 1, 2 & 3.

34. Current Science.
    Vol. 13, Nos. 9-10, 12.
    Vol. 14, Nos. 1 to 10 except No. 3.

48. Instituto Botanico de la Universidad Centeral, Quito.
    Ano. IV, Num 5, Junio 1945.

51. The Journal of the Southern Appalachian Botanical Club (Castanea).
    Vol. X, Nos. 1, 2, 5-6, 7-8.

54. The Journal of the Bombay Natural History Society.
    Vol. XLIV, Nos. 3, 4.

56. The Journal of the Mysore University.
    Sec. B. contr. 4 in Bt.
    Vol. II Pt. XVI contr. 8, III, XXIII.

86. Transactions of the Royal Society of South Africa.
    Vol. XXX, Pt. 2, 1944.
    ,, XXXI, Pt. 1, 1945.

113. Proceedings of the National Institute of Sciences of India.
    Vol. IX, Nos. 1, 2.
    ,, X, No. 1.

123. Lloydia (A quarterly Journal of Biological Science).
    Vol. 7, Nos. 2, 3.
    ,, 8, No. 1 March 1945.

124. Proceedings of the Leeds Philosophical & Literary Society.
Scientific Section.
Vol. III, p. XI,
,, IV, 1, 2, 3.
Index III, 35-40.

126. Transactions of the Bose Research Institute, Calcutta.
Vol. XIV, 1939-41.
,, XV, 1942-43.

133. Science Museum Library (Weekly List of Accessions to the Library).
Nos. 732-735, 736-739, 740-744, 745-748, 749-752, 753-757, 758-761 and 762-765.

136. Journal of the Department of Science, Calcutta University.
Vol. I, No. 4.

137. F. E. Fritsch.
The Structure and Reproduction of the Algae,
Vol. II.

138. S. D. Garrett.
Root Disease Fungi.

139. The Journal of the Madras University.
B. Sci. XV, No. 1, 1943.

140. The Proceedings of the National Academy of Science, India.
1944, Part 6, Vol. 14, Section B.

141. The Proceedings of the Indiana Academy of Science.
1938, Vol. 47
1939, Vol. 48
1940, Vol. 49
1941, Vol. 50
1942, Vol. 51
1943, Vol. 52
1944, Vol. 53 (2 copies).

142. United States Department of Agriculture.
Miscellaneous Publication No. 60—List of Available publications.

143. F. C. Bawden.
Plant Viruses and Virus Diseases.

APPEN

INDIAN BOTANI

Receipts and Payments Account for the

RECEIPTS

	Rs.	A.	P.	Rs.	A.	P.
To Opening Balance—With Editor	101	4	2			
With Business Manager ...	159	15	3			
With Secretary, ...	1	15	0			
With Imperial Bank of India ...	2,955	14	3	... 3,209	0	8
To Grant-in-Aid.						
Madras University ...	150	0	0			
Travancore University ...	100	0	0			
National Institute of Science from The Rockefeller Fund ...	750	0	0	... 1,000	0	0
To Subscriptions.						
Ordinary Members ...	1,344	12	0			
Life Members ...	443	12	0	... 1,788	8	0
To Subscription for Journal:						
Inland ...	918	0	0			
Foreign ...	390	10	0	... 1,308	10	0
,, Subscriptions in Advance				... 30	0	0
,, Sale Proceeds of back volumes				... 178	4	0
,, Sale of Reprints				... 151	6	9
,, Difference in Exchange				... 42	15	7
Total				... 7,708	13	0

A. C. JOSHI,
Hony. Treasurer.

We beg to report that we have examined the above statement for the year ended 30th September, 1945 with the books, counter- therewith.

Kashmere Gate, Delhi.
Dated, the Seventh day of December, 1945.
T. C.

DIX B.

CAL SOCIETY

year ending Septembes, 1945.

PAYMENTS.

		Rs. A. P.		Rs. A. P.
By Printing Charges:				
Journal	...	496 3 0		
1945 Year Book	...	129 5 0		
Sundries	...	41 12 0	...	667 4 0
By Railway Freight and cartage			...	263 11 0
,, Audit Fees			...	40 0 0
,, Clerk's Remuneration			...	20 0 0
,, Postage			...	57 10 6
,, Bank Charges	...	23 11 0		
Less received	...	7 2 0	...	16 9 0
,, Miscellaneous			...	33 15 0
Chief Editor:				
By Establishment	...	300 0 0		
,, House Rent	...	144 0 0		
,, Contingencies	...	59 6 8		
,, Postage	...	39 8 3		
,, Bank Charges	...	0 6 0	...	543 4 11
Business Manager:				
By Establishment	...	75 0 0		
,, Railwav freight, and cartage	...	28 6 0		
,, Postage	...	10 4 6		
,, Stationery	...	2 0 0	...	115 10 6
Secretary:				
By Establishment	...	200 0 0		
,, Postage	...	73 3 3		
,, Contingencies	...	28 11 6	...	301 14 9
By Closing Balance with Treasurer.				
Cash in hand	...	408 1 3		
Imperial Bank of India	...	5,154 4 7		
With the Editor	...	33 15 3		
With Secretary	...	52 8 3	...	5,648 13 4
		Total	...	7,708 13 0

of Receipts and Payments account of the Indian Botanical Society foil receipts and vouchers and have found the same in accordance

WALTER, CHAUDICK & CO.
CHARTERED ACCOUNTANTS,
Registered Accountants.

LIST OF MEMBERS

Honorary Members

Date of election

1936 Blackman, Frederick Frost, D.Sc. (Lond.), F.R.S., *late Reader in Botany, University of Cambridge*, Upper Cross, Storey's Way, Cambridge, England.

1946 Blackman, V.H., Sc.D., F.R.S., *Emeritus Professor of Plant Physiology, Imperial College of Science and Technology*, 17, Berkeley Place. *Wimbledon, S.W. 19*, England.

1933 Bower, Frederick Orpen, M.A., Sc.D. (Cantab.), D.Sc. (Dub., Sydney, Leeds), LL.D. (Aberd., Glas., Bristol), F.R.S., F.R.S.E.,F.L.S., *Emeritus Regius Professor of Botany, University of Glasgow*, 2, The Crescent, Ripon, Yorkshire, England.

1937 Darlington, C.D., Ph.D., D.Sc., F.R S., *Director John Innes Horticultural Institution*, Mostyn Road, Merton Park, London, S.W. 19, England.

1946 Halle, T. G., *Professor, Naturhistoriska Riksmuseum, Paleobotaniska Avdeln.*, Stockholm 50, Sweden.

1939 Fritsch, Felix Eugen, Ph.D. (München), D.Sc. (Lond.), F.R.S., F.L.S. *The Botany School*, Cambridge, and 34 Causeway Side, Cambridge.

1932 Fyson, P.F., M.A., I.E.S. (*Retired*). C/O The High Commissioner for India, London, England.

1935 Wieland, G.R., Ph.D., *Professor of Botany, Yale University* New Haven, Connecticut. U.S.A.

Ordinary Members

(The names of Life Members are marked with an asterisk)

1939 Abeywickrama, B.A., University of Ceylon, Colombo, 'Pepiliyana', Boralesgamuwa, Ceylon.

(*Ecology, Physiology, Anatomy and Economic Botany.*)

1945 Adatia, Dr. R.D., D.Sc., Professor of Botany, Wilson College, Bombay.

1945 Agarwala, Shirish Chandra, M.Sc., Research Assistant, Mango Necrosis Scheme, (I.C.A.R.), Botany Department, the University of Lucknow, Lucknow.

(*Plant Pathology and Physiology.*)

1920 *Agharkar, Shankar Purushottam, M.A. (Bom.), Ph.D. (Berl.), F.L.S., F.N.I., Ghose Professor of Botany and Head of the Department of Botany, Calcutta University, 35, Ballygunge Circular Road, Calcutta.

(*Systematic Botany, Ecology, Plant Geography, Aquatic and Marine Flora.*)

Date of election

1941 Ahmad, Ghias-ud-Din, B.Sc. Agri. (Panj.), B.Sc. (Lond.), M.S. (Calif.), Bar-at-Law, Assistant Professor of Botany, Panjab Agricultural College, Lyallpur.

(*Plant Physiology, Genetics.*)

1920 *Ajrekar, Shripad Lakshman, B A. (Bom. et Cantab.), Diploma in Agriculture (Cantab.), F N.I., I.E.S. (*Retired*), Bhandarkar Institute Road, Poona 4.

(*Mycology and Plant Pathology.*)

1928 *d'Almeida, J.F.R., B.A., M.Sc., Professor of Botany, St. Xavier's College, Hill Road, Bandra, Bombay.

(*Ferns, Marsh and Aquatic Plants.*)

1939 Anand, Pyare Lal, M.Sc. (Panj.), Ph.D. (Lond.), Professor of Biology, Sanatana Dharma College, Lahore, and Lecturer in Botany, Panjab University.

(*Ecology aud Taxonomy of Marine Algæ*).

1944 *Asana, Dr. Rustom D., M.Sc. (Bom.), Ph.D., (Lond.), D.I.C. (Lond.), Sugarcane Physiologist, Central Sugarcane Research Station, Pusa, Bihar.

(*Plant Physiology.*)

1946 Awasthi, Dharni Dhar, M.Sc., Research Assistant, Mango Necrosis Scheme (I. C. A. R.), Lucknow Universtiy, Lucknow.

(*Mycology and Plant Pathology*),

1928 *Bagchee, Krishnadas, M.Sc. (Cal.), D.Sc. (Lond.), D.I.C., F.N.I., Mycologist, Forest Research Institute, New Forest, Dehra Dun.

(*Cytology, Plant Genetics Mycology and Plant Pathology,*)

1943 Bakshi, Bimal Kumar, M.Sc., Lecturer in Botany, Rajshahi College, Rajshahi, Bengal.

(*Mycology and Systematic Botany.*)

1941 Banerjee, Sachindra Nath, M.Sc. (Cal.), Assistant Lecturer in Botany, Calcutta University, 35, Ballygunge Circular Road, Ballygunge, Calcutta.

(*Mycology and Plant Pathology.*)

1930 Banerji, Ilabonto, M.Sc. (Cal.), D.Sc. (Cal.), Lecturer in Botany, Calcutta University, 131, Harish Mukerji Road, Kalighat, Calcutta.

(*Cytology and Plant Breeding.*)

1926 Baria, Mrs. D.D.H. (née Kanga), M.Sc. (Bom.), "Panorama", 203, Walkeshwar Road, Malabar Hill, Bombay 6.

(*Physiology, Histology, Morphology and Cytology.*)

Date of election

1943 Bhaduri, Paramnath, M.Sc. (Cal.), Ph.D. (Lond.), F.L.S., F.R.M.S. Lecturer in Botany, University College of Science. 35, Ballygunge Circular Road, P.O. Ballygunge, Calcutta.

(*Cyto-Genetics.*)

1920 Bhakay, Gadadhar Narayan, M.Sc. (All.), Professor of Biology, Lucknow Christian College, Lucknow.

1920 Bharadwaja, Yajnavalkya, M.Sc. (Panj.), Ph.D. (Lond.), F.L.S., F.N.I. University Professor and Head of the Department of Botany, Benares Hindu University.

(*Algology, Limnology, Ecology, Bryology, and Economic Botany.*)

1933 Bhargava, Hari Raman. M.Sc. (Agra), Research Student, Deoartment of Botany, Agra College, Agra.

(*Morphology and Cytology of Angiosperms.*)

1944 Bhargava, Kameshwar Sahai, M.Sc., D.Phil. (Alld.), Asstt. Professor of Botany, Birla College, Pilani (Jaipur State).

(*Cytology of Fungi, Mycology and Pathology.*)

1937 Bharucha, Fardunji Rustomji, B.A., B.Sc. (Bom.), M.Sc. (Cantab), Dr. és Sc. (Montpellier), F.N.I., Professor of Botany, Royal Institute of Science, Bombay.

(*Phytosociology, Plant Physiology, Evolution, Genetics and Systematic Botany.*)

1945 Bhate, Prabhakar D., M.Sc., Lecturer in Biology, Wadia College, Poona.
(*Bryophyta, Pteridophyta.*)

1945 Bhatt, Rama Shanker, M.Sc., Ph.D., Research Assistant, Mango Necrosis Scheme (I.C.A.R.), Botany Department, University of Lucknow, Lucknow.

(*Plant Pathology and Mycology.*)

1945 Bhattacharjee, Sunil Kumar, B.Sc. (Hons.), Cal. Univ. Professor, Sri Aurobindo Asram, Pondicherry.

(*Systematic Botany & Genetics*).

1920 *Biswas, Kalipada, M.A. (Cal.), D.Sc. (Edin.), F.R.S.E., Superintendent, Royal Botanic Garden, Sibpur, Calcutta.

(*Algology, Systematic Botany and Ecology.*)

1939 *Bor, Norman Loftus, M.B. (Dublin), D.Sc. (Edin.), F.L.S., I.F.S., F.N.I., C.I.E., C/o The High Commissioner for India, London. England. (*Gramineae and Plant Ecology.*)

Date of election

1920 Bose, Sahay Ram, M.A., Ph.D., F.R.S.E., F.N.I., Professor of Botany, Carmichæl Medical College, 1, Belgachia Road, Calcutta.

(*Anatomy and Cytology of Higher Fungi, especially Polyporaceae.*)

1943 Chakravarti, Amal Kumar, M.Sc. (Cal.), Assistant Cytologist, Banana Research Scheme, Department of Botany, Calcutta University. 35, Ballygunge Circular Road, Calcutta.

(*Embryology and Cytology.*)

1945 Chakravarti, Hira Lal, M.Sc., Lecturer in Botany, Presidency College, Calcutta (on deputation). Dictionary of Economic Products & Industrial Research, 20, Pusa Road, New Delhi.

(*Anatomy, Systematic & Economic Botany*)

1944 Chakravarty, Madhusudan, M. Sc., Research Fellow in Botany, Calcutta University, College of Science. 35, Ballygunge Circular Road, Calcutta.

(*Floral Biology, Mycology and Plant Pathology.*)

1920 *Champion, Harry George, M. A. (Oxon.), C. I. E., F. N. I. Professor of Forestry, Imperial Forestry Institute, Oxford, England.

(*Ecology, Forestry and Physiology.*)

1946 Chandraratna, M. F., B. Sc., Hons. (Lond.), Ph. D. (Lond), D. I. C., Ag. Botanist to the Govt. of Ceylon, Department of Agriculture, Peradeniya, Ceylon.

(*Genetics.*)

1946 Chandrasekharan, M.A., Govt. Lecturing & Systematic Botanist, Agricultural College Research Institute, Coimbatore.

(*Applied or Economic Botany & Systematics*).

1945 Chatterjee, Dr. Debabrata, M.Sc. (Cal.), Ph.D. (Edin.), F.L.S. Lecturer in Botany, Cotton College, Gauhati, Assam.

(*Taxonomy, Plant Distribution, and Ecology.*)

1940 Chatterji, N. K., D. Phil. (All.), Lecturer in Botany, Dacca University, Ramna Dacca.

(*Plant Physiology and Plant Pathology.*)

1945 Chatterji, Dr. U. N., B. Sc. (Hons.), M. Sc., D. Phil. (Alld.), Research Scholar, Botany Department, University of Allahabad, Allahabad.

(*Plant Physiology.*)

Date of
election

1943 Chaturvedi, Suraj Bhan, M.Sc., Assistant Professor of Botany, Maharaja's College, Jaipur, Jaipur State, Rajputana.
(Fungi, Angiosperms, Floral Anatomy and Embryology).

1945 Chaudhury, S.D., Ph. D., D.I.C., Economic Botanist, Shillong.
(Plant Patholgy, Mycology, Plant Physiology and Genetics).

1943 *Chavan, Appa Saheb Ram Chandra Rao, B. S., (Bombay). Ph. D. (Neb., U.S.A.), Professor of Biology, Baroda College, Juna Modikhana, Baroda.
(Ecology, Grasses, Bryology.)

1945 Chinoy, Jamshedji Jijibhoy, M. Sc., Ph. D., Second Asstt. Economic Botanist, Imperial Agricultural Research Institute, New Delhi.
(Plant Physiology).

1939 Chopra, Ram Saran, M.Sc. (Panj.), Demonstrator in Botany, Panjab University, Lahore.
(Bryology.)

1937 *Chowdhury, Kafiluddin Ahmad, B.A. (Cal.), M.Sc. (Syracuse), D. Sc. (Edin.), F. N. I., Wood Technologist, Forest Research Institute, New Forest, Dehra Dun.
(Anatomy, Physiology and Palæobotany.)

1945 Chowdhury, N. P., M. Sc., Technical Assistant, Dictionary of Economic Products and Industrial Resources of India, 20, Pusa Road, New Delhi.
(Economic Botany, and Morphology.)

1943 Chowdhury, Sudhir, M. Sc., B. Sc. (Agri.), Assoc. I. A. R. I., Plant Pathological Laboratory, Sylhet, Assam.
(Mycology and Plant Pathology.)

1944 Craig, William Morison, E. C. 9462 Lieutenant, Cipher officer, C/o Lloyds Bank Ltd., New Delhi.

1943 Damle, Vasudeo Purushottam, M. Sc, Head of the Biology Department, Pratap College, Amalner E. K.
(Mycology, Physiology and Ecology.)

1920 Das, Atulananda, F. L. S., I. F. S. (Retd.), F. R. S. E., Chief Forest Officer Baripada, Mayurbhanj State.
(Systematic Botany and Forest Ecology.)

1945 Das, Kumudabhiaram, M. Sc., Lecturer, College of Agricultural Research, Benares Hindu University.
(Agricultural Botany.)

Date of election

1935 *Das Gupta, S. N., M. Sc. (Cal.), Ph. D. (Lond.), D. I. C. Reader in Botany, The University, Lucknow.
(*Mycology and Plant Pathology.*)

1922 Dastur, Rustom Hormasji, M. Sc. (Bom.), F. L. S., F. N. I., Institute of Plant Industry, Indore
(*Plant Physiology.*),

1944 Desai, Ramakant Madhav Rao, B. Sc., M. Sc., (Bom.), Professor of Biology, Dharmendrasinghji College, Rajkot, Kathiawar.
(*Physiology, Anatomy, Ecology and Cryptogams.*)

1945 Deshpande, R.B., M. Ag., Asstt. Economic Botanist, Imperial Agricultural Research Institute, New Delhi.
(*Plant Breeding and Genetics.*)

1945 Deshpande, Shankar Rangnath, M. Sc. (Bom.), Asstt. Professor of Biology, S. P. College, Poona 2.
(*Bryophytes, Pteridophytes and Morphology.*)

1945 Desikachary, T. V., M.Sc., Demonstrator, Presidency College, Madras.
(*Algae, Pharmacognosy*).

1945 Doraiswami, S., M. Sc., Jun. Lecturer in Botany, Univeristy Botany Laboratory, Triplicane, Madras.
(*Algae and Hydrobiology.*)

1935 Dutt, Nand Lall, M. Sc. (Panj.), Government Sugarcane Expert, Imperial Sugarcane Station, Lawley Road P. O., Coimbatore.
(*Economic Botany and Genetics.*)

1941 Fotidar, A. N., M. Sc. (Benares), A. I. F. C., K. F. S., Assistant Conservator of Forests, Kamraj Division, Baramulla, Kashmir.
(*Plant Ecology, Forestry and Flora of Kashmir.*)

1943 Ganguly, Ajit Kumar, M.Sc., Lecturer-Demonstrator in Biology, Ripon College, Calcutta 1. Sagar Dhar Lane, P. O. Beadon Street, Calcuatta.
(*Anatomy, Mycology and Plant Pathology.*)

1944 Ghosh, S. S., M. Sc., Assistant Wood Technologist, Forest Research Institute, New Forest, Dehra Dun.
(*Anatomy of Living and Fossil Plants especially wood.*)

1939 Ginai, M. Asgar, M.Sc. (Panj.), Assistant Mycologist, Fruit Experimental Station, Quetta.
(*Mycology, Agronomy and Horticulture.*)

Date of election

1943 *Gonzalves, Mrs. Ella, B.A., M.Sc., Assistant Lecturer, Royal Institute of Science, Dept. of Botany, Mayo Road, Bombay 1.

(*Algology.*)

1939 Gorrie, R. Maclagan, D.Sc., F.R.S.E., I.F.S., Forest Office, Lahore.

(*Forest Ecology, Grassland Ecology, Soil erosion.*)

1946 Gulatia, Harbans Lal, M.Sc., Teacher, Science Department, Aitchison College, Lahore.

(*Plant Pathology.*)

1933 Gupta, Babu Lal, M.Sc. (All.), Lecturer in Botany, Agra College, Agra.

(*Morphology of Angiosperms.*)

1935 Gupta, Din Dayal, B.Sc., Hons. Agri. (Wales), Dy. Asst. Director of Purchase, Directorate General of Food, Jamnagar House, New Delhi.

(*Plant Breeding, Genetics, Cytoloy, Plant Pathology and Improvement of Grasslands.*)

1945 *Hsü, Jen, Assistant Professor of Botany, National Peking University, China.

(*Palaeobotany and Structural Botany.*)

1939 Iyengar, C. V. Krishna, M.Sc. (Mad.), D.Sc., Assistant Professor of Botany, Intermediate College, Mysore.

1920 Iyengar, Màndayam Osuri Parthasarathy, M.A. (Mad.), Ph.D. (Lond.), F.L.S., F.N.I., Professor of Botany Andhra University Waltair.

(*Algæ*).

1943 Jacob, K.T., M.A. (Mad.), Ph.D. (Lond.), Cytogeneticist, Bose Institute, 93, Upper Circular Road, Calcutta.

(*Cytology and Genetics.*)

1922 *Janaki Ammal, Miss E.K., M.A., (Mad.), D.Sc. (Michigan), John Innes Horticultural Institution, Mostyn Road, Merton Park, London, S.W. 19.

(*Cytology, Genetics and Ecology.*)

1945 *Johansen, Dr. Donald A., 861 Columbia Avenue, Pomona, California.

1945 Johar, Dayal Singh, M.Sc., Microbiologist, Indian Institute of Fruit Technology, Lyallpur.

(*Plant Pathology and Microbiology of canned foods.*)

Date of
election

1933 Johri, Brij Mohan, D.Sc. (Agra), Head of the Biology Department, Bareilly College, Bareilly.

(Morphology of Angiosperms, Pteridophytes and Gymnosperms.)

1945 Joshi, A B., M.Sc., Asstt. to the Imperial Economic Botanist, Imperial Agricultural Research Institute, New Delhi.

(Genetics, Cytology and Plant Breeding.)

1930 Joshi, Amar Chand, D.Sc. (Panj.), F.N.I., Professor of Botany, Government College, Lahore.

(Morphology, Cytology and Economic Botany.)

1946 Joshi, Prakash Chandra, M.Sc., Department of Botany, Panjab University, Lahore.

(Embryology and Anatomy of Flowering plants, Pharmacognosy.)

1946 Kadam, Baburao Shankarrao, M.S., Ph.D., (Cornell) Asst. Agricultural Commissioner to the Government of India, Imperial Council of Agricultural Research Institute, New Delhi.

(Cytology and Genetics.)

1939 Kajale, Laxman Balwant, D.Sc. (Benares), Department of Biology, Meerut College, Meerut.

(Morphology of Angiosperms.)

1944 Kanitkar, Upendra Keshav, B.A., M.Sc., Professor of Botany, Sri Parashuram Bhau College, Poona 2,

(Plant Physiology, Plant Pathology.)

1921 Kanjilal, Praphulla Chandra, B.Sc., I.F.S., 4, Rai Behari Lal Road, Lucknow.

(Taxonomy, Ecology.)

1946 Kapoor, Lachman Das. M.Sc. (Agr. Bot.), Offg. Botanist, Drug Research Laboratory, Jammu, Kashmir.

(Systematic Botany especially of medicinal, poisonous and other economic plants.)

1943 Kar, Baikuntha Kumar, M.Sc. (Allahabad), Dr. Phil. (Leipzig), Plant Physiologist, Bose Institute, 93, Upper Circular Road, Calcutta.

(Plant Physiology.)

1925 Kausalya, Miss C.K., B.A., B.Sc. (Lond.), Professor of Natural Science, Queen Mary's College, Madras.

(Plant Pathology.)

Date of election

1943 Kausik, S.B., M.Sc., D.Sc., Lecturer in Botany, Central College, Bangalore.

(Floral Morphology and Embryology of Angiosperms.)

1944 Khan, Muhamadkhan Sardarkhan, B.Sc., 2544 Jogawada, Nasik City.

(Taxonomy of Angiosperms and Ecology.)

1946 *Khan, Raja Mohd. Mustafa Ali, Taluqdar, Utraula Estate, Gonda, U. P.

(Agriculture and Plant Diseases.)

1934 *Khanna, Lalit Prasad, M.Sc. (Panj.), F.L.S., formerly of Rangoon University: Present address, Dept. of Botany, Ewing Christian College, Allahabad,

(Plant Parasitic Nematodes and Liverworts.)

1935 Kolhatkar, Govind Gopal, M Sc. (Bom.), Assistant Professor of Botany, Fergusson College, Poona.

(Pteridophytes and Angiosperms.)

1946 Kovoor, A. T , Research Student, University Botany Laboratory, Triplicane, Madras.

1939 Kumar, Krishna, M.Sc. (Benares), Assistant Professor of Plant Physiology, Institute of Agricultural Research, Benares Hindu University.

(Plant Physiology, Genetics and Plant Breeding.)

1936 *Kundu, Balai Chand, M.A. (Cal), Ph.D. (Leeds), F.L.S., Director, Indian Central Jute Committee, Jute Agricultural Research Laboratories, P. O. Tejgaon, Dacca.

(Plant Anatomy, Charophytes, Mosses and Systematic Botany.)

1946 Lakhanpal, R.N., M.Sc., Research Scholar, Botany Department, The University, Lucknow.

(Palaeobotany.)

1944 Lal, Akshaibar, M.Sc., Ph.D. (Lond.), D.I.C., Asst. Professor of Plant Pathology, Benares Hindu University,.

(Plant Pathology, Plant Physiology and Crop Botany.)

1944 Lal, Kashi Naresh, M.Sc., D.Sc., Lecturer, Institute of Agricultural Research, Benares Hindu University, Benares.

(Plant Physiology and Plant Nutrition.)

1946 Mackenzie, Miss A. H., M.Sc., Research Scholar, Botany Department, The University, Lucknow.

(Bacteria and Plant Pathology.)

Date of election

1937 *Mahabale, Tryambak Shankar, B.A., M.Sc., Ph.D. (Bom.), Dept. of Biology, Gujarat College, Ahmedabad.
(Cryptogams, Ferns and Morphology.)

1927 *Maheshwari, Panchanan, D.Sc. (All.), F.N.I., Reader and Head of the Botany Department, Dacca University, Ramna P.O., Dacca (on Leave); c/o Botany Department, Harvard University, Divinity Ave, Cambridge, Mass., U.S.A.,
(Morphology and Cytology of Vascular Plants and Micro-technique.)

1929 *Majumdar, Girija Prasanna, M.Sc. (Cal.), Ph.D. (Leeds), Professor of Botany, Presidency College, Calcutta and Lecturer in Botany, Calcutta University; 19, Ekdalia Place, Ballygunge, Calcutta.
(Plant Anatomy.)

1945 Mani, V.S., M.Sc., Research Assistant, Botany Section Imperial Agricultural Research Institute, New Delhi
(Plant Physiology.)

1946 Mehra, Pran Nath, M.Sc., D.Sc., Offg. Head of the Botany Department, Panjab University, Lahore.
(Cytogenetics, Pteridophytes and Gymnosperms.)

1945 Mehrotra, Anant Prasad, M.Sc. (Alld.), Research Scholar, Empress Victoria Reader, Dept. of Botany, University of Allahabad, Allahabad.
(Plant Physiology.)

1926 Mehta, Rai Bahadur Karam Chand, M.Sc. (Panj.), Ph.D., Sc.D. (Cantab.), F.N.I., Professor of Botany, and Principal, Agra College, Agra.
(Mycology.)

1949 Mehta, Khusi Ram, M.Sc. (Panj.), Ph.D. (Luck.), Professor of Botany, Benares Hindu University.
(Anatomy, Palæobotany.)

1935 Misra, Parasuram, M.Sc. (Cal.), Ph.D. (Leeds), Head of the Department of Botany, Ravenshaw College, Cuttack.
(Plant Physiology and Cryptogams.)

1942 Misra, Ramdeo, M.Sc. (Benares), Ph.D. (Leeds), Head of the Botany Department, University of Saugor, Saugor.
(Ecology, Physiology and Plant Geography.)

1928 Mitra, Ajit Kumar, M.Sc. (Luck.), Ph.D. (Cantab.), Economic Botanist to the Government of U P., Nawabgunj, Cawnpore.

Date of election

1945 Mitra, Anil Kumar, B.Sc. (Hons.), M.Sc. (Alld.), Lecturer in Botany, University of Allahabad. 22, K.P., Kakkar Road, Allahabad.

(Algæ, Fungi and Plant Pathology.)

1943 Mitra, Miss Eva, M.A., Ghosh Research Scholar in Botany, Calcutta University; 14, Chowringhee Terrace; Elgin Road P.O., Calcutta.

(Systematic Botany.)

1920 Mitra, Rai Bahadur Sochindra Nath, B.Sc., Dy. Conservator of Forests, Divisional Forest Officer, Sundarbans Division, Khulna, Bengal.

1925 Monica, Mother, M.B A., L.T., Professor of Botany, Loreto House, 7, Middleton Row, Calcutta.

(Algæ and Palæobotany.)

1942 Mooney, Hebert F., M.A. (Oxon.), O.B.E., Sc.D. (Dub.), I.F.S., Chief Forest Adviser, Eastern States, Sambalpur (Orissa).

(Systematic Botany and Ecology.)

1943 Mukerjee, Susil Kumar, M.Sc. (Cal.), Ph.D. (Edin.), Curator of the Herbarium, Royal Botanic Garden, P.O. Botanic Garden, Sibpur, Howrah.

(General Morphology, Taxonomy and Systematic Botany.)

1942 Mukherjee, Subodh Gopal, M.Sc., Lecturer and Acting Head of the Department of Botany, Jagannath Intermediate College, Dacca.

(Physiology and Plant Anatomy.)

1943 Mukherjee, Sunil Kumar, M.Sc. (Cal.), Assistant Cytologist, Mango Research Scheme, Dept. of Botany, Calcutta University, 35, Ballygunge Circular Road, Ballygunge, Calcutta.

(Systematics and Cytology.)

1937 Mulay, Babu Narhar, M.Sc., Ph.D. (Bom.), Assistant Professor of Biology, D. J. Sind College, Karachi.

(Pteridophytes, Gymnosperms and Genetics.)

1943 Murthy, Saragur Narasimha, B.Sc. (Hons.), M.Sc., Head of the department of Biology and Professor of Botany, Lingaraj College, Belgaum.

(Morphology and Cytology.)

1943 Nag, Prabhat Chandra, B.Ag. (Bom.), B.A., B.L., Entomological Assitstant, Surma Valley and Hill District, Sylhet, Assam.

(Physiology, Mycology and Systematic Botany.)

Date of election

1939 Nandi, Hirendra Kumar, M. Sc. (Cal.), Ph. D. (Lond.), F. L. S., Economic Botanist to the Government of Assam, Shillong.

(Genetics, Cytology, Plant Breeding, Plant Physiology, Anatomy and Sytematic Botany.)

1946 Nigam, Shyam Sunder, M. Sc., Senior Scientific Assistant, 18/214 Kursawan, Cawnpore.

(Mycology and Plant Pathology).

1931 Nirula, R.L., B. Sc. Hons. (Panj.), Ph. D. (London), D. I. C., Head of the Department of Botany, College of Science, Nagpur.

(Plant Pathology, Algæ and Floral Morphology.)

1928 Oldroyd, Miss R. H., M. A. (Kansas), Department of Botany, Isabella Thoburn College, Lucknow.

1945 Oza, Jayantilal Devshankar, M. Sc. (Bom.), Department of Biology, Gujarat College, Ahmedabad.

(Mycology, Plant Pathology, Plant Anatomy.)

1937 Pal, Benjamin Peary, M. Sc., Ph. D. (Cantab), F.L.S., Imperial Economic Botanist, Imperial Agricultural Research Institute, New Delhi.

(Plant Genetics, Plant Breeding and Charophyta.)

1945 Pal, Dr. N. L., D. Sc. (Alld.), Lecturer in Botany, University of Allahabad. Canning Road, Madhoopur, Allahabad.

(Plant Physiology.)

1922 Pande, Shiva Kant, M. Sc. (Panj.), D. Sc. (Luck.), Lecturer in Botany, The University, Lucknow.

(Bryology, Cytology and General Morphology.)

1944 Pantulu, Jayanti Venkanna, M. Sc., Demonstrator in Biology. Maharaja's College, Vizianagram.

(Cytology, Genetics and Cytoecology.)

1946 Pant, Divya Dharshan, M.Sc., Lecturer in Botany, Allahabad University, Allahabad.

(Morphology of Angiosperms and Palæobotany.)

1921 *Parija, Prankrishna, B. Sc. (Cal.), M. A. (Cantab.), D. Sc., F. N. I., I. E. S., O. B. E., Vice-Chancellor, Utkal University, Cuttack.

1945 Puri, Gopal Singh, B. Sc. (Hons.), M. Sc. (Panj.), Ph.D. (Luck.), Botany Department, University College, London (England.)

(Palæobotany and Systematic Botany.)

Date of election

1936 Puri, Vishwambhar, D. Sc. (Agra), Professor and Head of the Dept. of Biology, Meerut College, Meerut.

(Anatomy, Morphology and Systematic Botany.)

1945 Pushkar Nath, M. Sc., Ph. D., Superintendent, Potato and Wheat Breeding Station,Simla.

(Systematic and Agricultural Botany.)

1939 Qazilbash, Nawazish Ali, M.Sc. (Panj.), Professor of Botany, Islamia College, Peshawar.

(Flora of N. W. F. Province, Botany and Chemistry of Ephedra and Artemisia.)

1931 Raghavachari, M.S., M.A., Professor of Botany, St. Berchman's College, Chenganacherry, Travancore.

(Ecology and Cryptogams.)

1931 Raghavan, Tiruviladur Srinivas, M. A. (Mad.), Ph. D. (Lond.), F. L. S., Professor and Head of the Department of Botany, Annamalai University, Annamalainagar.

(Cytology and Morphology of Angiosperms.)

1943 Raghava Rao, K. V., M. Sc. (Mysore), Demonstrator in Botany, Hindu College, Guntur, Madras.

(Morphology of Angiosperms and Plant Physiology.)

1946 Rai, Jagdish Narain, M. Sc., Research Scholar, Botany Department, The University, Lucknow.

(Plant Pathology and Mycology.)

1930 *Raizada, M. B., M. Sc. (Alld.), Forest Research Institute, New Forest, Dehra Dun.

1946 Ramanujam, S., M. A., Ph. D. (London), Second Economic Botanist, Imperial Agricultural Research Institute, New Delhi.

(Cytology, Genetics and Plant Breeding.)

1946 Ramakrishnan, K. V., Research Student, University Botany Laboratory, Triplicane P. O., Madras.

1936 Randhawa, Mohindra Singh, M. Sc. (Panj.), F.N. I., I.C.S., Secretary, Imperial Council of Agricultural Research, New Delhi.

(Algæ.)

1920 Ranade, S. B., B. A., M. Sc. (Bom.), Lecturer in Botany, Ismail College, Andheri, Jogeshwari P. O., Bombay.

1922 *Ranjan, Shri, M. Sc. (Benares et Cantab.), Dr. és Sc. (Toulouse), Professor of Botany, The University, Allahabad.

(Plant Physiology.)

Date of
election

1943 Rao, C. Surya Prakasa, M. Sc., Lecturer in Botany, Erskine College of Natural Sciences, Andhra University, Guntur, Madras.

(*Algology and Taxonomy.*)

1935 *Rao, H. Sitarama, D. Sc. (Luck.), Economic Botanist, Essential Oil Advisory Committee, Forest Research Institute, New Forest P. O., Dehra Dun.

(*Plant Morphology and Palæobotany.*)

1922 *Rao, L. Narayana, M Sc., Ph.D. (Lond.), Professor of Botany, Central College, Bangalore.

1937 Rao, V. Sitarama, B. A. (Andhra), M. Sc. (Benares), Professor of Botany, Ramnarain Ruia College, Matunga, Bombay. 19

(*Morphology, Anatomy and Cytology of Angiosperms.*)

1944 Rao, Y. Sundar, M. Sc., Lecturer Botany, Mrs. A. V. N. College. Vizagapatam.

(*Cytology and Embryology.*)

1935 Rapinat, A.S.J., Professor of Botany, St. Joseph's College, Teppakulam P. O., Trichinopoly.

(*Systematic Botany, Bryology, Lichens and Histology.*)

1942 Raychaudhuri, S. P., M. Sc. (Cal.), Assoc. I.A.R.I., Agricultural Officer, I. C. C. Scheme, Dept. of Plant Pathology, College of Agriculture, Poona 5.

(*Mycology and Plant Pathology.*)

1945 Razi, Basheer Ahmad, M. Sc., Mysore University Research Scholar, 35 Ballygunge Circular Road, Calcutta.

(*Floristics and Plant Distribution.*)

1944 Reddy, K. M. K., M. Sc., Lecturer in Botany. Mrs. A. V. N. College, Vizagapatam.

(*Embryology and Cytology.*)

1920 *Sabnis, Trimbak Sitarama, M. A., D. Sc. (Bom.), I. A. S., 8/2 Nawabganj Road, Nawal Niwas, Cawnpore.

(*Systematic Botany, Physiology, Anatomy, Teratology, Variegation and Genetics.*)

1939 Sachar, Gurcharan Singh, M.Sc. (Panj.), Ph. D. (London), D.I.C., "Ajit Lodge", Murree, Panjab

(*Mycology, Plant Pathology and Algæ.*)

Date of
election

1945 Sadasivan, T. S., M. Sc., Ph. D. (Lond.), Director, University Botany Laboratory, Triplicane. Madras.

(*Plant Pathology, Plant Viruses, Mycology and Plant Physiology.*)

1920 *Sahni, Birbal, M.A., Sc.D. (Cantab.), D.Sc. (Lond.), F.R.S., Prof. of Botany, The University, Lucknow.

(*Palæobotany.*)

1939 Saksena, Ram Kumar, M.Sc. (Benares), Dr. és Sc. (Paris), Reader in Botany, The University, Allahabad.

(*Fungi.*)

1946 Saksena, Shiv Dayal, M.Sc., Professor of Botany, Darbar College, Rewa (C.I.),

(*Palæobotany*).

1940 Sampath, Srinivasachari, M.A. (Mad.), Assistant Professor, Institute of Agricultural Research, Benares Hindu University, Benares.

(*Plant Karyology, Plant Breeding and Genetics.*)

1928 Sarbadhikari Prabhat Chandra, Ph. D., D.Sc. (Lond.), D.I.C., F.L.S., Professor of Botany, and Head of the Department of Botany, University of Ceylon, Colombo, Ceylon.

(*Plant Cytology, Anatomy and Genetics.*)

1946 Sarojini, Miss T. S., Research Student, University Botany, Laboratory, Triplicane, Madras.

1939 Sawhney, Rai Bahadur Kalidas, M.Sc. (Panj.), Director, of Agriculture H.E.H. the Nizam's Government, Hyderabad, Deccan.

(*Agricultural, Economic and Applied Botany.*)

1932 Sayeed-ud-Din, M., B. Sc. (Bom.), M.A. (Edin.), F.R.M.S., F.L.S., Professor of Botany, Osmania University, Hyderabad, Deccan.

(*Systematic Botany and Ecology*)

1937 Sen, B., B.Sc. (Cal.), Director, Vivekananda Laboratory, Almora, U. P.

1944 Sen, Nirad Kumar, M. Sc., Lecturer in Botany, Presidency College, Calcutta.

(*Plant Physiology.*)

1935 *Sen, Pabitra Kumar, M.Sc., Ph. D. (Lond.), D.I.C., Physiological Botanist, Fruit Research Station, Sabour.

1935 Sen, Srish Kumar, Retired Extra Asst. Commissioner, 3/5, Puran Paltan, Ramna P. O., Dacca.

(*Systematic and Economic Botany and Ecology.*)

Date of election

1943 Sen Gupta, Jatis Chandra, M.Sc (Cal.), Dr. Phil. Nat (Heidelberg), Senior Professor of Botany, Presidency College, Calcutta and Lecturer, Calcutta University, 41, Lansdowne Terrace, Kalighat, P. O., Calcutta.
(*Plant Physiology, Ecology, Algæ*)

1945 Sen Gupta, Satya Ranjan, M.Sc., Ph. D. (Lond.), Professor of Botany, Ripon College, 24, Harrison Road, Calcutta.
(*Microbiology*.)

1941 Senaratna, S.D. J.E., B. Sc. (Lond.), Assistant in Systematic Botany, Department of Agriculture, Ceylon; and Sri Palee Hindagala, Peradeniya, Ceylon.
(*Systematic Botany, Morphology, Anatomy, Ecology and Genetics.*)

1920 *Sethi, Mehr Chand, M.Sc. (Panj.), Professor of Botany, Forman Christian College, Lahore.
(*Systematic Botany and Algology.*)

1945 Seikh, Abdul Hameed, M.Sc., Technical Assistant, Dictionary ofEconomic Products and Industrial Resources, 20, Pusa Road, New Delhi.
(*Mycology, Systematic Botany and Plant Physiology*)

1921 Shevade, S. V., B. Sc., Professor of Biology, M.T.B. College, Surat.
(*Taxonomy, Ecology, Plant Sociology and Cytology.*)

1940 Shukla, Vidya Bhaskar, M.Sc., Ph.D. (Luck.), Asst. Profesor of Botany, College of Science, Nagpur.
(*Palæobotany.*)

1944 Singh, Balwant, M.Sc., Forest Research Institute, New Forest, Dehra Dun, U.P.
(*Plant Physiology, Agronomy, Biochemistry and Agricultural Botany.*)

1945 Singh, Harbhajan, M.Sc., Assistant to the Imperial Economic Botanist, Imperial Agricultural Research Institute, New Delhi.
(*Plant Breeding, Genetics, Systematics.*)

1923 *Singh, Thakur Chandra Narayan, M.Sc., D.Sc. (Luck.), Agricultural Expert and Botanist, Horticultural Research Institute, Padhye-Gardens, Nagpur, Ajni, C. P.
(*Morphology.*)

1945 Sinha, Saligram, M.Sc., Ph.D. (Lucknow), Reader in Botany, Agra College, Agra.
(*Mycology and Plant Pathology.*)

Date of election

1939 Sircar, S., M. Sc. (Cal.), Ph. D. (Lond.), D.I.C., Lecturer in Plant Physiology in Calcutta University, 35, Ballygunge Circular Road, Calcutta.

(*Plant Physiology.*)

1945 Sitholey, Rajendra Varma, M.Sc., Ph.D. (Lucknow), Botany Department, Lucknow University, Lucknow.

(*Palæobotany.*)

1945 Som Prakash, M. Sc., Professor of Biology, R. E. I. Institute, Dayal Bagh, Agra.

(*Morphology of seed Plants and Plant Physiology.*)

1945 Srinivasachar, D., M.Sc., Assistant to the Imperial Economic Botanist, Imperial Agricultural Research Institute, New Delhi.

(*Genetics, Cytology and Embryology.*)

1946 Srinivasan, M. M., B.A., I.F.S., Botanical Forest Officer, and Silviculturist, Shillong.

(*Systematic Botany and Ecology*).

1945 Srivastava, J. G., M. Sc., Professor of Biology, C. & S. College, Shikarpur. Sind.

(*Mycology and Plant Pathology.*)

1945 Subrahmanyan, R., M.Sc., Research Student, 52 Choolai High Road, Madras.

(*Algæ.*)

1945 Subramanian, C. V., B.Sc. (Hons.), Research Student, University Botany Laboratory, Madras.

(*All phases of Botany.*)

1944 Swamy, B. G. L., B. Sc. (Hons.), C/o D. V. Gundappa Esq., Basavanagudi, Bangalore.

1946 Tandon, Kailash Nath, M. Sc., Assistant, Wood Technology Section, Forest Research Institute, Dehra Dun.

(*Anatomy of living and fossil plants.*)

1946 Thampan, K. Damodaran, M. Sc., Lecturer in Botany, Zamorin's College, Chalapuram, Calicut.

(*Algæ and Angiosperms.*)

1946 Thankam, Miss C., Research Student, University Botany Laboratory, Triplicane, Madras.

1945 Tiwari, Devi Datt, M. Sc., Research Scholar in Botany, Department of Botany, University of Allahabad, Allahabad.

(*Mycology.*)

Date of
election

1920 *Tiwary, Nand Kumar, M.Sc. (Alld.), Assistant Professor of Botany, Benares Hindu University.

(*Morphology, Ecology and Bryophytes*)

1945 Tiwari, S. D. N., M.Sc. (Nag.), Indian Forest College, New Forest, Dehra Dun.

(*Systematic Botany and Plant Breeding.*)

1945 Trivedi, Bhim Shanker, M Sc., Research Assistant, B.O.C. Plaeobotanical Research, Botany Department, The University, Lucknow.

(*Palæobotany.*)

1937 Vaheed-ud-Din, Syed, M. Sc., Ph. D. (Minnesota), Plant Pathologist, H. E. H. the Nizam's Government, Agricultural Department. Hyderabad, Deccan.

(*Plant Pathology and Mycology.*)

1926 Vakil, Bomanji Naoroji, M. Sc., Adenwalla Mansion, 11, Chaupathy, Seaface, Bombay.

(*Ecology, Physiology, Mycology, Pathology, and Systematic Botany.*)

1945 Varardpande, K. V., M.Sc. (Benares), Assistant Professor of Botany, College of Science, Nagpur.

1945 Varma, Jagdish Chandra, M.Sc., Research Scholar in Botany, 12, Chatham Lines, Allahabad.

(*Mycology and Cytology*)

1945 Venkataramani, K S., M. Sc., Research Scholar, University Botany Laboratory, Madras.

(*All phases of Botany*).

1936 Venkateswarlu, Jiliella, M.Sc. (Benares), Lecturer in Botany, Erskine College of Natural Sciences, Andhra University, Guntur.

(*Morphology and Cytology of Angiosperms, Pharmacognosy and Medicinal Plants.*)

1931 Venkateswarlu, V., M.A., Lecturer in Botany, Hindu College, Masulipatam,

(*Cytology and Anatomy.*)

1945 *Verma, Girja Shanker, M.Sc. (Lucknow), Lecturer in Botany, Botany Department, Lucknow University, Lucknow.

(*Mycology and Plant Pathology.*)

Date of
election

1945 Vishwanath, K. V., M. Sc., Technical Assistant, Dictionary of Economic Products and Industrial Research, 20 Pusa Road New Delhi.

(*Economic Botany and Plant Genetics*)

1946 Yogeswari, Miss L., Research Student, University Botany Laboratory, Triplicane Madras.

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